RURAL TRANSPORT ISOLATION AND HEALTH OUTCOMES: RESULTS FROM THE SWISS RED CROSS SURVEY IN LAO PDR

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Abstract: Despite inter-sectoral approaches to reduce poverty and increase health outcomes, there are few investigations dealing explicitly with transport provision and health outcomes in developing countries. The 1998 Swiss Red Cross survey in rural Lao PDR is described where nutritional status as an indicator of health was established for every child under five years in 99 villages in Luang Prabang province. Mothers with young children were interviewed to assess their attitude towards health practices. Individual measurements were taken on a census of 3,440 children to establish anthropometric-nutrition: mid-upper arm circumference (MUAC); height-for-age; and weight-for-age. (3,043 cases for MUAC). They were analysed for the relationships between malnutrition and village isolation from the road and waterway transport systems, and other social and environmental explanatory variables. Village isolation is expressed as accessibility to the transport system and travel times to the nearest district town centre. Multi-variate statistics (logistic regression) determine the main explanatory factors contributing to measures of malnutrition in rural areas of which isolation is statistically significant.

Key Words: Transport, accessibility, health, malnutrition, rural Lao

1. INTRODUCTION

Work in progress at the World Bank aims at developing a tool-kit for planners on poverty and transport based on an extensive literature review by Booth, Hanmer and Lovell (2000). A seminar convened in Washington, D.C. in June 2000 attempted to identify suitable case studies, but few were identified that linked the transport and health sectors with the notable exception of HIV-aids in Africa. One case study of poverty and accessibility in East Indonesia (Black, *et. al.*, 2000) identified the poorest villages but did not assess the health status of those individuals in the village. Data from the Swiss Red Cross project 'Support of the Health Services in Luang Prabang, North Laos', sponsored by 'ProVictimis', has allowed us to investigate rural isolation and malnutrition amongst children. Swiss Red Cross (SRC) has been supporting Luang Prabang health services for more than ten years with a present focus is on activities in Sub-district Health Centers providing primary health care to small rural villages.

Lao People's Democratic Republic (Lao PDR) is an appropriate case study to explore the linkages between the transport and the health sector. Sufficient food and nutrition are basic conditions for good health, yet one third of the families in Lao PDR lack sufficient food supply. A large proportion of the population suffers from malnutrition due to interacting factors such as poverty, inadequate food supply, improper diet, inadequate access to health services, and poor child rearing practices. Isolation and poor rural transport are contributing factors. Food supply and consumption vary amongst ethnic groups, depending on geographic location, level of income and food availability and production (ADB, 2000). At the core of the Government's National Socio-economic Development Plan for 1996 – 2000 was infrastructure development and poverty reduction, especially in the rural and multi-ethnic areas. A physical target set for 1998 – 2002 in the Fourth Five-year Plan is the reduction of protein-energy malnutrition (PEM) in children under five from 40 per cent to 20 per cent.

Amongst the most obvious problems of protein-energy malnutrition are weight and subcutaneous fat losses, muscle wasting, edema, lethargy and, ultimately, death. Other consequences of malnutrition include impaired immune responses, decreased cardiac and respiratory function, and delayed wound healing that has slower recovery with higher risk of clinical complications (Kelly, 2000). Malnutrition in children leads to growth retardation and slowed mental and social development, resulting in a poor start in life with consequences long into adulthood. Malnourished children may be abnormally thin for their height ('wasted') and /or abnormally short in stature with linear growth retardation ('stunted'). A diet predominantly based on rice and frequent infections, as in Lao PDR, are considered the major determinant of many micronutrient deficiencies - iodine deficiency leading to goiter and cretinism; vitamin A deficiency leading to xerophthalmia and blindness; vitamin B deficiency leading to beriberi; iron deficiency leading to anemia; and folic acid, calcium and mineral deficiencies.

The aim of the paper is to describe the survey design and statistical results obtained, not to prescribe policy intervention nor a physical infrastructure plan. The problem context of Lao PDR is outlined in Section 2. The international literature on malnutrition and the etiology and outcomes of protein-energy malnutrition is reviewed, and the different anthropometric measurements that are commonly used to assess the nutritional status of individuals and populations are explained in Section 3. The data collection phase is outlined in Section 4. Working hypotheses are that health outcomes are a function of one or more explanatory variables, such as village remoteness, ethnicity, gender and age, sanitation and access to water. Univariate and multivariate statistics are applied to identify the main explanatory factors of malnutrition based on three standard measurements (the dichotomous outcome variables in the logistic regression models are: **MUAC**, or mid-upper arm circumference; **HAZ**, or height-for-age, reflecting stunting; and **WHZ**, or weight-for-height, reflecting wasting). Sections 5 and 6 discuss the results, including the significance of isolation as an explanatory factor in rural malnutrition.

2. PROBLEM CONTEXT

Landlocked Lao People's Democratic Republic (Lao PDR) covers 236 800 sq km and is surrounded by Thailand, Cambodia, Vietnam, China and Myanmar. When it joined ASEAN and the ASEAN Free Trade Area in 1997 the Government's policy, New Economic Mechanism, had been in place for one year transforming the country of 4.9 million people from a centrally planned one to a market-oriented system. Its per capita income had reached US$400 until the Asian Economic Crisis saw annual inflation rise by 150 per cent, and the value of the kip (US$1 = 4735 kip, in March 1999) crash by 30 per cent in eighteen months (World Bank, 1999). In 1997, Lao PDR compared unfavourably with the average value of a number of key social indicators for East Asia and the Pacific (Table 1) and the deteriorating economic performance has had dire poverty consequences for one of the poorest and least developed countries of the region. The rural and agricultural (predominantly rice cultivation) sector employs 80 per cent of the workforce and generates half of GDP. Inflation and rising prices reduced real incomes and purchasing power leaving some households unable to meet their minimum food requirements and having to adjust their diets. The dramatic rise in the price of drugs (largely imported) resulted in increased dependence on cheaper, traditional medicines.

Table 1. Comparative Social Indicators - Lao PDR and Neighboring Regions, 1997

Social Indicator	Lao PDR	East Asia & Pacific
Life expectancy at birth (years)	53	69
Infant mortality rate (per 1000 live births)	101	39
Under 5 mortality (per 1000 live births)	140	47
Maternal mortality (per 100 000 live births)	650	N/a
Child malnutrition (% children less than 5)	40	16
Adult illiteracy (% population 15 & over)	43	17
Hospital beds (per 1000 people)	2.6	2.1
Physicians (per 1000 people)	0.2	1.4

(Source: World Development Indicators)

There is deep and pervasive poverty and poor health that has a strong regional and ethnic dimension. The rural poor are primarily farming households living at or below subsistence level. The incidence of poverty is higher in the south than the north, and lowest in the central region. The south is dominated by rural poverty. Half of the country's population lives in small, scattered villages without regular access to transport means. Regional disparities correlate with lack of all-weather rural access roads and a poor provision of social services and infrastructure. Lao PDR's transport system of roads, inland waterways and air services are "rudimentary, dilapidated, and unreliable" (World Bank, 1997, p.1) and much of the basic has deteriorated through lack of regular maintenance.

Road transport carries move than 90 per cent of freight ton-km and 85 per cent of passenger-km (World Bank, 1997, p.2). The dominant transport mode for access is therefore roads. Despite the Government allocating half of public expenditure to transport in 1990 – 1995 only 16 per cent of the 6442 km national road network is classified as in "good condition". Most of the provincial roads (7135 km) and about 8050 km of local tracks are impassable during the rainy season. The role of air transport is modest: there are two international airports

(Vientiane and Luang Prabang) and 17 smaller airports and airfields that are connected by a small national airline service. About 1190 km of the Mekong River is navigable depending on the season. River transport is of the small-scale artisanal type because the efficient use of large cargo vessels is precluded due to seasonal constraints of river depths, and difficult channels. River port construction is uneconomic because of the extreme fluctuations in water level, and navigation aids are largely absent. Thus, the 16 provinces plus Vientiane and the special zone of Xaisomboune are poorly integrated in a physical way.

Luang Prabang is one of the larger provinces, situated in the North of Laos, with a population of 365 000 (Lao State Planning Committee, 1997). Mountains and large areas of dense forest cover the province. At present, Luang Prabang is divided in 11 districts, each of them divided in about 10 sub-districts. The provincial capital Luang Prabang, population 64 000, is situated on the Mekong River. Transport by river, mainly along the Mekong, and three large tributary rivers, is still an important way of communication with the rural villages. One recently renovated major road crosses the province, and is the only South to North axis through the country. The climate, as in the rest of Laos, is characterized by the monsoon, with the dry and hot season peaking in April, hot and heavy rains towards August, and cool and humid weather around December. Economic activities are mainly agriculture, forestry and tourism (the old city of Luang Prabang is World Hertitage listed), with very little small industry.

3. LITERATURE

The literature review defines briefly different forms of malnutrition and the etiology and outcomes of protein-energy malnutrition, and the different anthropometric measurements that are commonly used to assess the nutritional status of individuals and populations. Improvements to these measurements and reference populations are being developed. Despite limitations (Boss, 1994), the current practices are still valuable and can give comprehensive information on the nutritional status of individuals and populations.

Even in non-emergency times, protein-energy malnutrition is a problem in many developing countries, most commonly affecting children between the ages of 6 months and 5 years. The condition may result from lack of food or from infections that cause loss of appetite while increasing the body's nutrient requirements and losses. Children between 12- and 36-months old are especially at risk since they are the most vulnerable to infections such as gastroenteritis and measles. Chronic protein-energy malnutrition has many short-term and long-term physical and mental effects, including growth retardation, lower resistance to infection and increased mortality rates in young children (WHO, 2000). Children above one year old have an increased risk of malnutrition also because they require high- energy intake to support their growth and to allow for increased mobility. This coincides with the period of weaning when the child is receiving less breast milk and has to adjust too fast to adult nutrition. Young children often get squeezed having to compete for breast milk with a new born and for other food with older siblings. Although most children in Laos are breast fed, exclusive breast feeding is rare and complementary feeding practices are largely inadequate providing insufficient additional intake (WHO, 1999).

In recent literature, we can find many suggestions as to the causes and etiology of protein-energy malnutrition, or the anthropometric manifestations of it. The WHO Expert Committee on Physical Status (1995) groups the determinants as being more immediate, such as inadequate dietary intake and diseases, or as being more distant (or intermediate via causal pathways), such as poverty and economic background, low parental education, poor water supply and sanitation, poor access, poor food security, inadequate health care, cultural factors and taboos, and child care practices. One immutable environmental factor that has effect on growth but is not associated with socioeconomic status is altitude; high altitude leads to reduced birth weight and lesser subsequent growth.

The most detailed study examining the statistical relationship between factors associated with malnutrition in children, representative for Laos nationwide, is the FAO 1995 survey 'Diagnosis of the nutrition situation and food consumption in Laos', also called the 'Laos Nutritional Assessment survey' (LNAS). The LNAS study found the following risk factors for stunting in under 5-year old children, after. Characteristics of the mother, including a height below 1.45 m is shown to be a significant risk (RR=1.30; CI 95%=1.07-1.57) for stunting of her child, as is a weight of the mother below 45 kg (RR=1.16; CI=1.06-1.77), and the mother's education: incomplete primary education (RR=1.24; CI1.12-1.37). Living conditions also determine the risk of stunting. Children are at risk for stunting if the house that shelters the family is cramped: i.e. less than 5 m^2 per person (RR=1.13; CI=1.05-1.23), has more than 1.5 people per room (RR=1.22; CI=1.07-1.4), has a straw roof (RR=1.84; CI=1.26-2.69), has bamboo walls (RR=1.56; CI=1.22-2.01), is not lit by electricity (RR=1.15; CI=1.03-1.28), and uses wood for fuel (RR=1.31; CI=1.04-1.65). The absence of a latrine is also strongly associated with stunting (RR=1.22; CI=1.11-1.34).

The standard of living also affects stunting. Children are at higher risk for severe stunting if the household has less than 3 draught animals (RR=1.17; CI=1.01-1.36), has non-irrigated land (RR=1.32; CI=1.08-1.62), and cannot meet the family needs with its rice harvest (RR=1.19; CI=1.04-1.37). Household possessions reflect the economic status, and the absence of the following belongings influence the risk of stunting: no fridge (RR=1.70; CI=1.22-2.38), or no motorcycle (RR=1.48; CI=1.21-1.80). Finally the characteristics of the village also contribute to stunting: isolation (far from main road, no passenger transport, school far from village), lack of health facilities, no permanent market, no electricity network, and absence of a vaccination program in the last 3 years (FAO, 1995).

The applications of anthropometry are important for public health and clinical decisions that affect the health and social welfare of individuals and populations (WHO Expert Committee on Physical Status, 1995a; de Onis, 1997). There are many measurements available to assess the nutritional status of children and adults regarding protein-energy deficiency. In a landmark 452 page report, the WHO Expert Committee on Physical Status (1995) proposes a division according to age in 7 groups, to decide what measurement and interpreting techniques should be used for nutritional assessment of a person. The seven groups are: pregnant and lactating women; the newborn infant; infants and children; adolescents; overweight adults; thin adults; and those over 60 years of age. Here, we consider only under-nutrition - not overweight - of children between 6 months and 5 years of age, excluding the issues surrounding low-birth weight. In normal non-emergency situations and where breast-feeding is universal, children under 6 months are less likely than older children to be malnourished and interpretation of anthropometric findings in babies tends to be inaccurate. Therefore, children under 6 months are often excluded from nutrition surveys, as we have done.

Basic anthropometric measurements include weight, height and circumferences. Anthropometric indices are combinations of measurements. They are essential for the interpretation of measurements: it is evident that a value for body weight alone has no meaning unless it is related to an individual's age or height. Measurements of weight and height can be combined to produce indexes, for example the body mass index (weight/height^2). Weight may be related to height through the use of reference data and can then be expressed in terms of z-scores, percentiles or percent of the median. The term 'indicator' relates to the use, or application, of indices. The indicator is often constructed from indices. For example, the proportion of children below a certain level of weight-for-age is widely used as an indicator of community status.

A simple method to ascertain the nutritional status of child populations is the measurement of MUAC (Mid-Upper Arm Circumference of the left arm). Between the age of one and five years, the arm circumference of a healthy child varies little, an increase of about 2 cm: with the median MUAC for boys increasing from 15.7 cm to17.4 cm and for girls from 15.1 cm to 17.3 cm (WHO/NCHS reference data, de Onis, 1997a). During this period the MUAC reflects a rough estimate of the nutritional status of the child. Measurement of the MUAC is fast and appears simple, but is a less reliable indicator with frequent differences in results from different surveyors. A single cut-off point (generally 12.5 cm), which is based on observations on normal well-fed Polish children in the early 1960's, has been used over the last decades for children under five years of age (Mei, 1997). If the circumference measures below 13.5 cm the child is suspected to be malnourished. If the circumference measures below 12.5 cm the child is suspected to be severely malnourished (Briend, 1985). Those children should be referred to a health post for further follow up. In a population of children it is normal to have 5% of them with a MUAC less than 125mm. The nutritional status of the population should be followed up when between 5% and 10% have a MUAC less than 125. The situation is alarming if more then 10% is under that threshold and grave if more than 20% is under 125mm. The number of children with a MUAC less than 110mm gives the best estimate of the proportion of the child population at risk of dying from malnutrition.

Although the measurement of MUAC is relatively simple, its usefulness is limited by considerable inter-measurer error as well as inter-measurer error, and classification bias by fixing the cut-off point at 125mm, 130mm or 135 mm. Moreover the inherent measuring error is large at 1 cm, which is as large as the difference of –2 and –3 z-score. Age does have a distorting effect on the MUAC values, leading to overestimating malnutrition in young children and underestimating malnutrition in older children. Therefore sometimes 2 cut-off points are used for different age groups, although this may complicate the interpretation. A more useful role for MUAC may be as a screening measurement in the triage of large numbers of children for enrollment in selective feeding programs rather than a measurement of malnutrition prevalence in population surveys (Boss, 1994). Note that a MUAC-for-age or MUAC-for-height measurement can also be expressed in z-scores (Mei, 1997). The WHO now plans to develop MUAC-for-age reference tables (de Onis, 1997).

A measuring stick sometimes used in fieldwork, and relying on MUAC-for-height, was developed in the 1960's: the 'QUAC-stick' or Quaker Arm Circumference measuring stick. In this method, the MUAC is measured and compared with the child's height, as measured with the stick. With the publication of new MUAC-for-height reference data, a WHO-modified QUAC-stick has been proposed (Mei, 1997).

The WHO Expert Committee on Physical Status (1995a) stresses the importance of choosing the best indicator and the best cut-off point to use in anthropometric screening. Universal cut-off points are often recommended but are appropriate only if resources are adequate to handle all individuals selected for intervention. Cut-offs are commonly set on the basis of experience in affluent populations, and show the proportion of individuals identified by screening, who can benefit from further diagnostic steps or intervention. These cut-offs are usually described in terms of z-scores, percentiles or percent of a normative median, because historically reference data from healthy populations were used to establish these values. Nonetheless, despite the poor theoretical basis for using reference data in this way, these cut-offs have been tested empirically in affluent populations and are now conventional. They should not be abandoned until cut-offs based on sounder principles have been validated (WHO Expert Committee on Physical Status, 1995a).

4. STUDY DESIGN

4.1. Cross-sectional study

The design chosen in this health survey is a cross-sectional study. A survey was used to assess the health status of children in the target area of six new rural health centers. The survey was done in February 1998, towards the dry season, when the food reserves should be plenty (after the rice harvest in December) and the farmers slash the bush to let it dry and then burn a few months later. There was no specific ethics approval procedure. The survey was one of the planned activities in the Memorandum of Understanding between the Swiss Red Cross project and the Laos PDR Ministry of Health. The project was fully integrated in the Provincial Health Services of Luang Prabang, and was approved. Provincial and district administration and health services cooperated actively during the preparation and implementation of the survey. Individual identities are kept confidential.

Potential weaknesses linked to the cross-sectional study design were addressed during the design and analysis phases. Random error was reduced by the large population size and by doing a census for the anthropometric data collection, as well as a census of all villages for demographic and environmental information. Random error was reduced in the MCH (Mother and Child Health) questionnaire by first interviewing all mothers and then taking a systematic sample of one third on the questionnaires for analysis, after return to the provincial capital. Selection bias, which is a systematic error, was avoided for the above reasons and thanks to a very high response rate. Non-differential measurement bias must be present as it is inherent to anthropometric measurement techniques, but was addressed during the surveyor training. Recall bias, where the interviewed mother of a sick child may remember more detail of any possible risk factor, and observer bias where the surveyor's appreciation of a minority ethnic group may have influenced the observation, were targeted during the training of the surveyors. The training of surveyors also included efforts to reduce interviewer errors such as asking errors by changing the wording of the questions, probing errors, recording errors and cheating by recording a response when a question was not asked or not answered.

4.2 Sample and response rate

A census was done covering all 99 villages located in the 6 sub-districts. All villages cooperated well which led to a 100% response rate. None of the villages were excluded during the data cleaning process. The survey found that 15 villages (6 340 people, or 23% of the sample population) were predominantly Lao Lum, 64 villages (14 342 people or 52%) were Lao Tung, 8 villages (1 974 people or 7%) were Lao Sung, and 12 villages (4 770 people or 17%) were of mixed ethnicity.

A census was done on all children 0 to 59 months (under 5-year olds) who were registered during a meeting with village leaders and elderly at the start of each visit in the village. This list may be considered as very accurate, as villages have on average just 40 under five year children (median 36, minimum 5, maximum 143 children). Bigger villages are divided in quarters with a responsible person per quarter, who knows the population well. The very high response rate may be due to the traditional attitude of rural villagers and their compliance with the authority of the district accreditation letter and village head decision power, as well as the good logistic preparation and methodical execution by surveyors.

4.3 Instruments and questionnaire

Age assessment: The age of the child is asked to the mother of the child. When the mother does not know the exact age of the child a calendar of yearly events is used to estimate the month of birth. These yearly events include ceremonies and the agriculture cycle. For each of the three ethnic groups a specific calendar is used. There is no civil status registration in Laos to register births and deaths, and family record books or village records are rare. Age assessment is therefore less reliable, which is illustrated in frequency distributions of age in months, by 'heaping' or strong digit preference at multiples of 6 or 12 months

Measurement of MUAC: Plastified paper strips, or arm circumference 'insertion' tape, provided by UNICEF, were used to measure the arm circumference. They show a scale in millimeters, three colored zones (green-yellow-red) to indicate normal circumference, moderately and severely low MUAC. MUAC is measured to the nearest millimeter, expressed in centimeter with one decimal. However, in practice the surveyors usually measured up to the nearest half-centimeter.

Measurement of weight: A hanging tubular spring scale was used, with a kind of loose pants or sling seat to put the child in. Weight is measured to the nearest 100 grams, or expressed in kilogram with one decimal. The spring scales have a screw to calibrate the scale to the zero-reading.

Measurement of height: Locally made wooden height measuring boards with a slide were used. Children under 2 years of age, or less than 85 cm tall, must be measured lying down, while older children are measured standing up. 2 surveyors or one surveyor with the help of a volunteer from the village must fix the child in correct position. Height is measured to the nearest centimeter, expressed in centimeters.

The surveyors conducted a structured interview with village leaders and representatives. A four-page form per village was available for the surveyors to record the information. The surveyors conducted a structured interview with each father and mother of a under two-year old child separately. A 12-page questionnaire for one father and mother was available for the surveyors to record the information.

4.4 Organization and implementation of data collection

Surveyors were 60 final-year students (40 were female) of two institutions: Auxiliary Nurses (second year) and Medical Assistants (third year) - 46 Lao Lum, 9 Lao Tung and 5 Lao Sung . The students were divided in teams of two or three, depending on the confidence they had. A team of three surveyors can manage to survey a village of less than 200 people in one and a half days. Bigger villages require several teams of surveyors to join and work together, so that the survey does not take more than 2 days. Seven teachers, as well as two directors of both schools were assigned as supervisors and join the survey activities. Several SRC project staff played the role of supervisor during the first week of the survey.

Reliable detailed maps of the region were not available. After meetings with district staff, and sometimes sub-district leaders prior to the survey, diagrams were drawn with schematic location of the villages in the sub-district, the distance in hours of walking between them, their estimated population and ethnicity. Villages do move in search of better agriculture ground (slash and burn cycle) and villages sometimes change their name, or are known under different names. People in remote villages often have no family name. With the diagrams of the area, the supervisors and surveyors drafted a survey calendar containing details on time for walking, meeting, measuring children and interviewing villagers

The standard chronology of a visit to a village is as follows:

- A messenger is sent to the village two or more days before the arrival of the surveyors.
- After the arrival of the surveyors, the team has a meeting with the village leader and elderly: the surveyors introduce themselves, present their accreditation (introduction letter), explain the aim of the survey, explain the sequence of activities, ask cooperation on a number of activities, identify suitable location to do the anthropometric measurements.
- Meeting with village leader and elderly: assess demographic parameters: births, infant and child deaths with reasons for death, maternal deaths, ask questions on availability of drinking water.
- Walk around village, with village representative, and count mosquito nets and toilets.
- Next day: organize anthropometric measurement and recording: take MUAC, height and weight of each child between 6 and 59 months (2 to 4 minutes per child)
  Ascertain that each child in the village has been seen.
- Interview each mother and father with a child under 2 years old. Complete questionnaire (20 minutes per parents).
- After the survey, offer free treatment for children who present with disease.

Preparation for the survey required a intensive logistic exercise to prepare measurement instruments and blank questionnaires for each team, decide on and purchase personal equipment to support the surveyors, organize medical supplies to treat children after the survey, arrange transport to the sub-districts, etc.

4.5. Field testing

A one-day field pilot test was attempted on 26/1/1998 in 6 rural villages close to the provincial capital and not part of the 6 sub-districts to be surveyed. Following an evaluation meeting an extra day class with all surveyors. Improvements were of three major kinds. Anthropometric measurement techniques and common errors were addressed during the extra day training. Most of these weaknesses in the questionnaire related to language and translation problems, using conditional phrasing or allowing subjective answers. Personal factors such as shyness, young inexperienced students, cultural tradition of putting great importance in age and status to define interpersonal relations, can interfere with required attitude of surveyors and a standard approach to village leaders was reviewed and practiced during role play exercises.

4.6. Two-weeks survey

Table 2 summarizes the details of the number of surveyors and survey days per sub-district. On 18/2/1998, all 60 surveyors and supervisors left Luang Prabang town by truck or speedboat towards their respective sub-districts. The minimum time spent in one sub-district to visit each village was 12 days. The maximum time spent was 18 days. Cumulatively, the surveyors spent 900 surveyor-days to survey all 99 villages. The total cost of the survey was $US 6,800.

Table 2. Number of surveyors and survey days per sub-district

Name sub-district	Number of villages in sub-district	Sub-district population	Number days survey	Number surveyors
Na Yang	12	5,107	13	6
Hat Sa	16	3,886	16	9
Pha Pai	22	6,311	14	12
Hat Pang	20	6,029	14	12
Ban Nong	17	3,480	18	15
Don Kham	12	2,619	12	6
TOTAL	99	27,432	900 surveyor-days	

5. UNIVARIATE ANALYSIS

The three measures of health outcome used in this study are MUAC (mid-upper arm circumference), stunting using HAZ (height for age expressed as a Z-score) and wasting using WHZ (weight for height as a Z-score). Analysis of variance (ANOVA) was used to test whether there was a significant difference in the means of each of these variables for the three categories of isolation –

- villages on the road;
- villages not on the road but less than a 1.5 kilometer walk form the road; and
- 1.5 kilometers or more walk from the road.

The means of MUAC at each level of increasing isolation were 14.28cm, 13.80cm and 13.96cm, respectively. The analysis revealed that there was a significant difference in the means ($F_{2,\ 3039} = 40.4$, $p<.001$). A post-hoc Scheffe test indicated that there was a significant difference in means between all levels of isolation. Means of stunting (HAZ) at each level of increasing isolation were –1.9SD (1.9 standard deviations below the standard), -2.1SD and –2.4SD, respectively. The analysis revealed that there was a significant difference in the means ($F_{2,\ 3437} = 47.0$, $p<.001$). A post-hoc Scheffe test indicated that there was a significant difference in means between all levels of isolation. There was no significant difference in the mean scores for wasting (WHZ) for each level of isolation. In the next section, further multivariate analyses of these factors are undertaken.

6. LOGISTIC REGRESSION

Three dichotomous outcome variables are considered in logistic regression models. **MUAC**, or mid-upper arm circumference, with cut-off points first 13.5cm and then 12.5 cm where we consider what effect the withholding of the independent variable [age] has on the regression. **HAZ**, or height-for-age, reflecting stunting where we take –2 z-scores as the cut-off point for moderate stunting; and subsequently –3 z-scores as the cut-off point for severe stunting. **WHZ**, or weight-for-height, reflecting wasting where we take –2 z-scores as cut-off point for moderate wasting; and –3 z-scores as cut-off point for severe wasting.

The 8 independent variables in the logistic regression are:

- **[ethnicity]** , categorical, reference category = 'Lao Lum' (set default at 'first');
- **[isolation]** , categorical, reference category = 'on main road' (set default at 'first');
- **[sex]** , dichotomous, reference category = 'male';
- **[water2]** , dichotomous, reference category = 'village with well, Gravity-fed water system or spring' as opposed to drinking from the river;
- **[age]** , continuous, reference to one unit of measurement (= 1 month);
- **[village size]** , continuous, reference to one unit of measurement;
- **[% of families with latrine]** , continuous, reference to one unit of measurement;
- **[nbr of bednets per family]** , continuous, reference to one unit of measurement.

Eight logistic regression models were run, depending on the outcome factor, and for MUAC, to determine whether age as independent factor plays a major role:

1. Discriminants for the dependent factor MUAC with cut-off 135mm, including age;
2. Discriminants for the dependent factor MUAC with cut-off 135mm, excluding age;
3. Discriminants for the dependent factor MUAC with cut-off 125mm, including age;
4. Discriminants for the dependent factor MUAC with cut-off 125mm, excluding age;
5. Discriminants for the dependent factor HAZ (stunting) with cut-off <-2 z scores;
6. Discriminants for the dependent factor HAZ (stunting) with cut-off <-3 z-scores;
7. Discriminants for the dependent factor WHZ (wasting) with cut-off <-2 z-scores;
8. Discriminants for the dependent factor WHZ (wasting) with cut-off <-3 z-scores.

6.1. Discriminants for dependant variable MUAC, with cut-off point MUAC < 135mm

The scores for the variable MUAC have been dichotomised into two categories: MUAC<135 and MUAC => 135 mm. These represent those children with severely or moderately small MUAC as opposed to children with normal MUAC measurements, respectively. The SPSS software determines which of the independent variables will be retained in the model, only choosing those that have a significant predicting power for the Odds Ratio of the outcome variable. The probability of the event (of having a MUAC reading under 135 mm) is expressed as: $P(event) = 1 / (1 + e^{-Z})$. The model estimated correctly 86% of the children with a normal MUAC above 13.5cm, and estimated correctly 63% of the children with a MUAC below 13.5cm. The explanatory variables are interpreted as follows.

Ethnicity: Lao Tung children are 1.8 times more likely (CI95%= 1.4-2.4) than Lao Lum, to have a MUAC below 135mm.
Isolation of the village: very remote villages (more than 1.5 hours walk to a road or navigable river) are 1.3 more likely (CI95%= 1.1-1.8) to have a MUAC below 135mm; and

fairly remote villages (less than 1.5 hours walk to a road or navigable river) are 1.7 times more likely (CI95%= 1.4-2.3) to have a MUAC below 135mm.
Sex: Girls aged 6 to 59 months are 0.8 less likely (CI95%= 0.7-0.9) to have a MUAC below 135mm, compared to boys.
Age: with each month increase in age, children are 0.92 (CI95%= 0.91-0.92) times less likely to have a MUAC below 135mm.

6.2. Discriminants for dependant variable MUAC, with MUAC <125mm and MUAC =>125mm

This analysis distinguishes between severely low MUAC and children with moderately low or normal MUAC. When lowering the MUAC cut-off point to 125mm, far fewer children will fall in the 'positive' category - in fact, only 201 children. Therefore the model is less useful in this case, as the model will predict all of the outcome cases as 'negative', and still gets an overall accuracy of 94%. Three determinants for a MUAC <125mm are retained by the model, with p<0.006:

Isolation of the village: very remote villages (more than 1.5 hours walk to a road or navigable river) are 1.7 times more likely (CI95%= 1.2-2.5) to have a MUAC below 125mm; and fairly remote villages (less than 1.5 hours walk to a road or navigable river) are 2 times more likely (CI95%= 1.3-3.1) to have a MUAC below 125mm.
Sex: Girls aged 6 to 59 months are 0.7 less likely (CI95%= 0.5-0.9) to have a MUAC below 125mm, compared to boys.
Age: with each month increase in age, children are 0.95 (CI95%= 0.94-0.97) times less likely to have a MUAC below 135mm.

6.3. Logistic regression: outcome variable HAZ or stunting with cut-off point HAZ <-2z and <-3z.

The cut-off point HAZ <-2z differentiates 'normal height' children from children who are moderately or severely stunted. The model has correctly predicted 76 % of the stunted children, and 49 % of the normal children. This gives the model an overall accuracy of 64 %. The model includes 5 dependent variables as determinants: [ethnicity], [isolation of the village], [age] and [village size]. All have a highly significant predicting power, with p<0.004. The variable [access to latrines] comes at a significance level of p<0.02. The following comments on the explanatory variables are relevant.

Ethnicity: Lao Lum and Lao Sung have very much the same pattern. Lao Tung are 1.6 times more likely (CI95%= 1.3-2.1) to be stunted.
Isolation of the village: the most isolated villages have significantly more stunted children. Children from these villages are 2.3 times more likely (CI95%= 1.7-2.9) to be stunted, than children from villages along the road or river, closer to the district town.
Village size: although village size has significant positive determination power, the likelihood of being stunted is hardly affected.
Access to a latrine, and age: although both variables have significant negative determination power, their effect on the likelihood of stunting is minimal.

However, if the cut-off point is HAZ<-3z (this differentiates between severely stunted children, and moderately-stunted or normal length children) then the number of 'positive' cases are reduced. However, the SPSS model can still correctly predict 9 % of the severely stunted, leading to an overall accuracy of 74 %. By lowering the HAZ cut-off to –3 z-scores, identifying the severely stunted, the model removes 2 of the 5 variables form the previous model. The remaining variables are the same: [**ethnicity**], [**isolation of the village**], and [**age**]. Their significance as determinant remains similar. The Odds Ratios for the likelihood of severe stunting remains the same for [**ethnicity**] and [**age**], and decreases a little for [**remoteness of the village**]. The predicting power of the variables [**access to latrine**] and [**village size**] is no longer significant and are removed from the model.

6.4. Logistic regression: outcome variable WHZ with cut-off point WHZ <-3z

The cut-off point WHZ <-3z differentiates between severely wasted children, as opposed to moderately wasted and normal weight children. By lowering the WHZ cut-off from –2 z-score to –3 z-score, the number of observed cases decreases from 321 children to 62 children. The model predicts all cases to be negative, and retains an overall accuracy of 98%. Determinants for severe wasting are [**ethnicity**] and [**age**]. For once, the model suggests the Lao Tung are doing much better, with an Odds Ratio of 0.4 to be less likely to be severely stunted (p<0.0009; CI95%= 0.21-0.66). Age is a very significant predictor, but has little impact on the likelihood of severe stunting (OR=0.95, CI= 0.93-0.97).

6.5. Discussion on determinants of malnutrition

Eight demographic and environmental independent variables have been entered in logistic regression models to determine the impact on three dichotomised indicators of malnutrition - **MUAC**, or mid-upper arm circumference; **HAZ**, or height-for-age, reflecting stunting; and **WHZ**, or weight-for-height, reflecting wasting. The occurrence of a moderately low **MUAC**, < 135mm, is determined by **ethnicity** (for Lao Tung: OR=1.8 compared to Lao Lum), by **isolation** of the village (for the most remote villages: OR= 1.3; for the fairly remote villages: OR=1.7 compared to villages on a road or river), by **sex** (for girls: OR= 0.8), and by **age** (per increasing month: OR= 0.9). When lowering the cut-off point to 125mm, severely low **MUAC** is determined by isolation, sex and age, with about the same Odds Ratios (OR). When the factor age is taken out of the model, there is little effect on the power of the other independent variables, except for a small increase in their Odds Ratios as would be expected.

The determinants for stunting are **ethnicity** and **isolation** of the village, for both moderate stunting (HAZ<-2 z) and severe stunting (HAZ<-3z). Lao Tung are more stunted than Lao Lum (OR= 1.6 for moderate stunting; up to OR=2.0 for severe stunting). Children of very remote villages are more often stunted than children from fairly remote villages. Determinants for moderate wasting (WHZ<-2 z) are the availability of **latrines** and **age**, while the determinants for severe wasting (WHZ<-3 z) are **ethnicity** and **age**.

Clearly, isolation of the village is one of the factors contributing to malnutrition, although not the only one. Its importance reinforces the need to carefully coordinate inter-sectoral policies for health and for transport, especially in countries where resources are scarce. Poor accessibility of the villages requires intervention in the transport sector that provides all-weather roads and a supportive road maintenance regime. Integrated rural development projects covering agricultural, health and transport and targeted towards the most remote regions of the country are required.

It may be thought that the variable **[ethnicity]** and **[isolation of the village]** are interlinked, and thus influence the outcome of the model, by being represented twice. Traditionally, it is said that Lao Lum (Thai ethnic group) inhabit the lowland valleys, that Lao Tung (of Khmer ethnicity) dwell on the mountain slopes, and that Lao Sung (hilltribes of Sino-Tibetian origin) inhabit the remote mountain tops. A Chi-square test shows indeed a very significant association between the attributes [ethnicity] and [isolation of the village], at $p<0.001$. As the association between these 2 categorical variables is not linear, a correlation test is not appropriate. The Pearson's correlation coefficient is non-significant and very low at 0.004 if for [ethnicity] we include all 4 categories (the 3 ethnic groups and 'mixed'). However, if the 12 villages of 'mixed ethnicity' are not entered in the Chi square test, the Pearson's correlation coefficient rises to a medium-high 0.64, with significance at $p<0.001$. When we run again the former logistic regressions, with alternatively excluding **[ethnicity]** or **[isolation]**, the outcome varies very little. The significance of either **[ethnicity]** or **[isolation]** on the change in Odds Ratio of the outcome is very similar in the models of the various anthropometric outcomes and we can therefore confidently conclude that [ethnicity] and [isolation] express similar but not identical characteristics. The regression model software retains both variables in the equation.

7. CONCLUSIONS

Despite the growing importance of inter-sectoral approaches to transportation there remain a paucity of data on the inter-relationships between transport and health in developing countries. This study provides analysis of data on a number of important indicators of health status in developing countries and risk factors. One of the risk factors identified in the study was levels of rural isolation as an indicator of transport infrastructure.

A Swiss Red Cross project Luang Prabang, North Laos has allowed us to investigate rural isolation and malnutrition amongst 3,440 children under 5 years of age. We have defined in some detail the different forms of malnutrition of etiology and outcomes of protein-energy malnutrition, and the accompanying anthropometric measurements (Section 3) and the study design to collect the data (Section 4). Individual measurements were taken to establish anthropometric-nutrition: mid-upper arm circumference (MUAC); height-for-age; and weight-for-age. Univariate and multivariate analyses were undertaken. Whilst not the only factor explaining malnutrition, as revealed by logistic step-wise regression, remoteness from the minimal transportation infrastructure of Laos is an important variable. Mid-upper arm circumference and stunting are more prevalent in villages more than 1.5 kilometers from the road.

Whilst the findings may not be surprising , we have been able to identify the statistically significant risk factors, quantify these risk factorsand control for them in a model. The model demonstrates that when other explanatory factors are controlled for, transport infrastructure has a statistically significant affect on health status measured through appropriate WHO indicators. .. Rural road access improvements in remote areas (with low potential traffic volumes) are difficult to justify on road-user benefits alone but would become justifiable when the health benefits are calculated, as we propose to do in a forthcoming paper. Rural health policies must be integrated with a transportation sector program of village access to improve health outcome in the remote areas of the developing world.

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