ENERGY FLOW STUDIES IN SOUTH PACIFIC POPULATIONS

By

Thomas T. Poleman

January 1974 No. 74-5

ENERGY FLOW STUDIES IN SOUTH PACIFIC POPULATIONS*

By

Thomas T. Poleman

It is a pleasure to report my observations on energy flows among the inhabitants of the South Pacific. These observations grow out of the curious economics of international air travel. Once you board a plane it rarely pays to get off. A few years ago I found myself doing research on the island of Mauritius, off the coast of East Africa. For only $24 more than the return fare to New York, I discovered that one could cross the entire Indian Ocean, span Australia, and island-hop home across the beautiful South Pacific. Two days were spent in Pago Pago, three in Tahiti. I also stopped for several hours at the Nandi airport, but it was too dark for close observation of the natives, and again in Honolulu. As the latter is no longer non-industrial, I will confine my remarks to Samoa and Tahiti.

I will also, since this group is heavily charged with anthropologists, attempt to structure my remarks along the lines customarily followed in ethnographies: folklore, sex, and the quest for food.

Under folklore comes dancing and the natives are much given to this. They shed their normal raiment and don grass skirts and Bikini[1/] tops. They then shake the skirts, flex their arms, hands, and fingers suggestively, and smile. All this is very demanding. Reliable estimates of the average energy cost are wanting, but it may well be of the order of the 8 Kcal/minute figure reported by Durnin and Passmore for Scottish country dancing.

---

* Prepared for the Workshop on Energy Flow in Non-Industrial Societies sponsored by the Social Science Research Council, 30 January-1 February 1974, Carnegie Endowment International Center, New York City.

1/ An atoll in the Marshall Islands.

Profound indeed are the social, historical, and economic implications. The shaking of the grass skirts involves considerable muscular dexterity and with time the pelvic muscles become uncommonly developed. That this enhanced their amatory capabilities was not lost on passing sailors: one consequence was that it took Captain Bligh two trips to get the breadfruit to Jamaica. Even today the natives quest little for food. It is offered by planeloads of tired (Japanese, of course) businessmen, the occasional yachtsman, and scholars too ancient to leap great waters in a single bound.

- - - - - - - - - - - - - - -

Less fleeting has been my work and thinking on energy flows in other less-developed areas, and it is to these that I now turn. What I have to report draws heavily on "The Economic Applications of Vital-Rate Monitoring," a recent compendium of some of the work we have been doing at Cornell (1). For the present this is still available gratis from the university, but is scheduled for proper book publication later in the year. Titled Bio-economics: Applications of Vital-Rate Monitoring to Developing Countries, it will then cost big money.

Summarized is the work of more than just one man. The 1968 project among Jamaican farmers was done by three students--Mike Schultheis, Dick Lockwood, and Ben Badjeck--working in close association with Miss Helen Fox and her associates in the Jamaican Scientific Research Council. Our project in the Philippines in 1971 was led by Weyland Beeghly and could not have been carried out without the close cooperation of teams from the Philippine Food and Nutrition Research Center led by Dr. Carmen Intengan and Dr. Patricia de Guzman and from the International Rice Research Institute directed by Dr. Randolph Barker. In what used to be Ceylon, now Sri Lanka, Dr. E. S. G. Hettiaratchi and his associates in the Medical Faculty of the University have been of great help, as has the group led by Dr. B. V. de Mel of the Medical Research Institute of Ceylon. At Cornell Professor N. R. Scott and Mr. Carl Czarniecki of the Agricultural Engineering Department and Professor R. B. Thomas of the Anthropology Department have been unfailingly helpful. And, last but not least, our equipment reflects the genius and friendship of Heinz Wolff, of the Bioengineering Division of the Clinical Research Centre in London. To the ignorant economist all have been kind to a fault.

I. MONITORING DEVICES: PROBLEMS, IMPROVEMENTS, MORE PROBLEMS

The KM Respirometer

A sequence of devices for monitoring energy expenditure of free-ranging man is shown in Figure 1. Pictured in the photograph of the "traditional" device (a) is the Kofranyi-Michaelis respirometer, the standard field instrument for energy studies. It consists of a small dry gas meter weighing about three kilograms, worn on the back and attached to a face mask. The subject, doing his usual work, breathes out through an expiratory valve, the expired air passing through the meter. A device within the meter directs a fraction of this air into a small rubber bladder. This air is then analyzed, oxygen uptake determined, and related to energy expenditure: a Kcal of expended energy being the equivalent of about 200 milliliters of oxygen.

The constraints to normal behavior imposed by such a device are obvious. Connections to the subject make communication difficult and its appearance may cause considerable embarrassment. The instrument's bulk makes it awkward for the subject to do some activities, and the weight affects energy expenditure during others. All these factors inevitably cause the individual to modify his behavior, resulting in invalid energy readings.

Some of these problems can be minimized by use of the KM-diary technique with which the work of Doctors Passmore and Durnin is most commonly associated. A continuous activity record is maintained by the subject or an observer during the study period. The oxygen consumption of principle activities is determined with the respirometer at a separate time. The energy expended for each activity is then calculated by

FIGURE 1. EVOLUTION OF MONITORING DEVICES USED FOR DETERMINING ENERGY EXPENDITURE OF FREE-RANGING MAN*

a. Respiration calorimetry with the KM respirometer

b. Monitoring of heart rate with radio biotelemetry

c. A SAMI for monitoring total heart beats in three rate ranges

d. The SATR system for systematic sampling of heart rate: signal conditioner on right and miniature cassette recorder on left.

*Photography: N. R. Scott, C. Czarniecki and T. T. Poleman; Equipment display: L. Bein; Chaperon: L. Morse.

multiplying the per minute caloric cost of the activity by the number of minutes spent doing it. Total energy expenditure for the period can be found by summing the expenditure for the various activities.

But this approach also has problems. It necessarily groups all activities into a few categories (e.g., sitting, standing, walking), thus glossing over the variation of daily life. Furthermore, there may be circumstances under which a diary observer is unable to keep accurate records, and to depend on the subject is always risky and sometimes impossible. In sum, the device is best suited for applications where the work is homogeneous and where it is possible to obtain meticulously accurate time span recording. Such conditions probably are not characteristic of pre-industrial societies.

Because of these problems with the traditional methodology and equipment, work physiologists welcomed the discovery that there exists what appeared to be a linear relationship between a person's cardiac output and his oxygen uptake over much of his range of activity. Such a relationship makes intuitive sense: if it is the circulatory system that supplies oxygen to the body, then the increased oxygen demanded by exertion can be supplied only by a greater flow of blood. The problem then, or so it seemed, resolved itself to establishing the link between heart rate and oxygen uptake that applied to each individual--a process we have come to call "calibration"--and then finding a means for monitoring his heart rate while he went about his regular activities.

My interest in energy expenditure began in 1968 and grew out of an interest in quantifying the calorie requirements of human populations. After due allowance is made for body size and age/sex, the principal determinant of calorie needs is activity patterns and little information of such patterns exists for those societies in which food problems are thought to exist. At about this time there first became commercially available miniature, yet reasonably long range, biotelemetry systems. Around one such system was organized in Jamaica during the summer of 1968 a cooperative inquiry into energy expenditure patterns of small-holding farmers.

Biotelemetry

Biotelemetry may be defined as the technique for obtaining biological data at one location and transmitting it to another where it may be observed or recorded. Transmission can be by wire, radio, microwave, optical, or pneumatic means; in practice though biotelemetry has come to mean radio transmission since it maximizes freedom of movement.

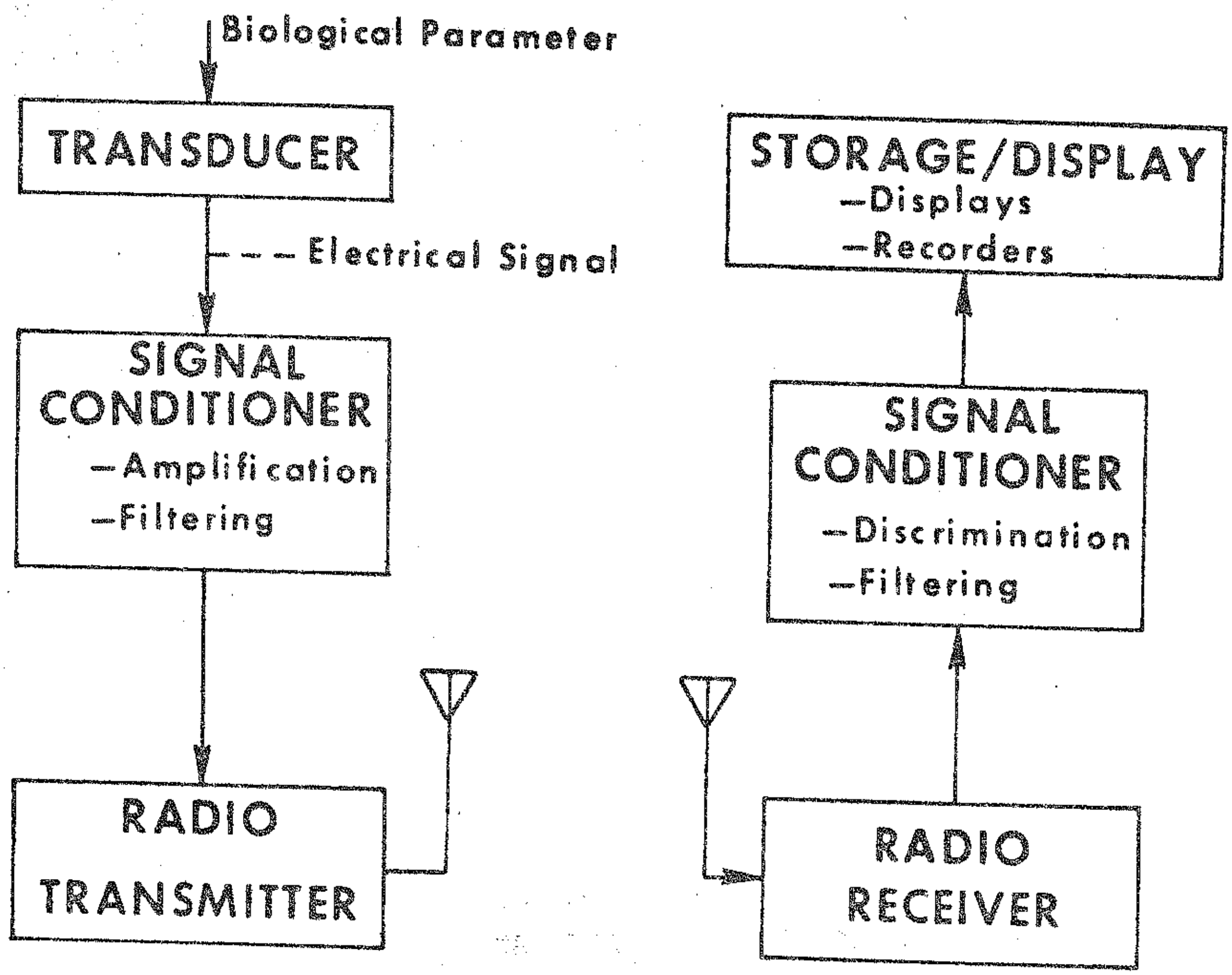
The basic components of a radio biotelemetry system are illustrated in Figure 2. Transducers convert the biological information into an electric signal for transmission. The requirement of the signal conditioning will depend on the type of transducer and the type of signal, but may involve amplification and filtering before the signal is suitable for transmission. In other systems the blocks shown in Figure 2 may be combined or eliminated. Heart rate telemetry, for example, is relatively simple: the electrodes serve as transducers and filtering is performed at the receiving end.

To transmit the transducer information through the air the conditioned signal is applied to a radio carrier of high frequency. Either the FM or AM frequency band may be used, but FM transmission is customary. Advantages of FM compared to AM are: greater signal-to-noise ratio, lower transmission power for a given transmission strength, and, because variations in signal amplitude are not critical, electrode positioning is easier.

The great advantage of radio biotelemetry, of course, is that the subject is relatively free to move about. Stress the word "relatively." As may be seen in Figure 1b--or better still in Figure 4, shot in Jamaica--the telemetry transmitter is not without disadvantages. If transmission is to exceed a few dozen meters it is necessary to use a rather long and conspicuous antenna. Though much less an impediment to normal behavior than the respirometer, it may nevertheless inhibit movement in performing some tasks and its conspicuousness is not conducive to relaxed behavior.

Additional limitations of biotelemetry to studies of free-ranging man are the constraints to distance and terrain it imposes, and the necessity for fairly complex receiving, storage, and retrieval equipment.

FIGURE 2. BASIC BLOCK DIAGRAM OF RADIO BIOTELEMETRY SYSTEM



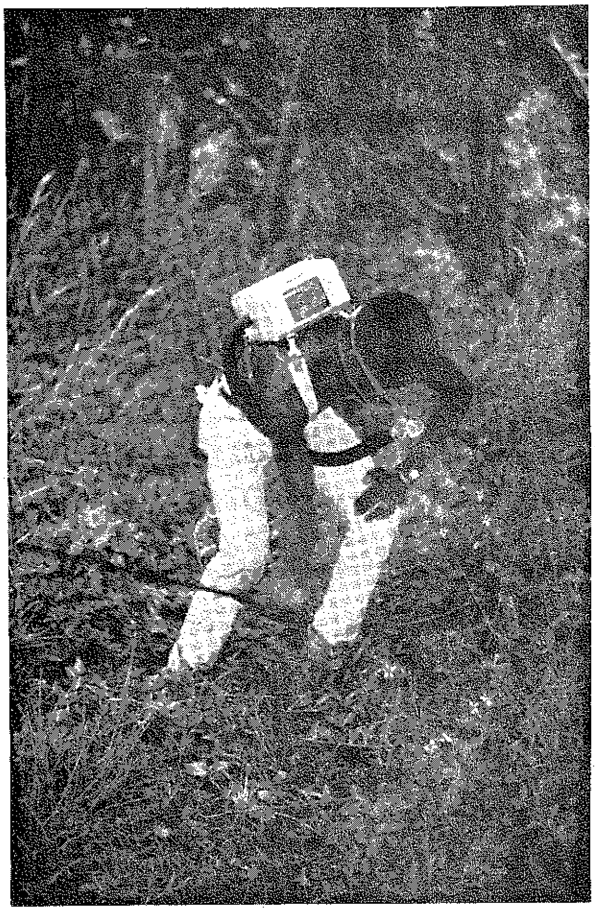


FIGURE 3. (left) TRADITIONAL CALORIMETRY: THE KM RESPIROMETER

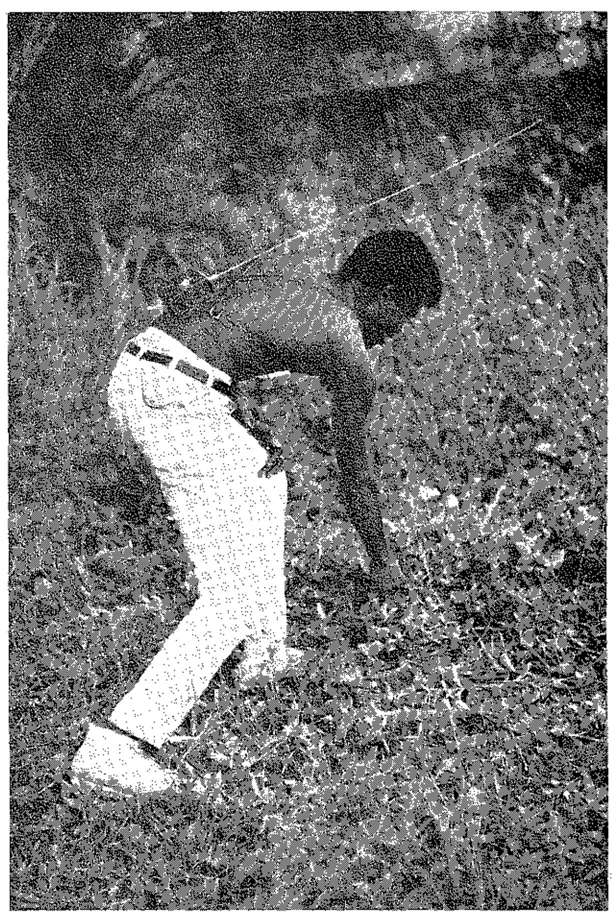


FIGURE 4. (right) MONITORING HEART RATE WITH TELEMETRY

Maximum transmission distance with the cigarette-packet sized transmitter used in Jamaica is of the order of 500-1500 meters line of sight. FM transmissions do not bend; just as Houston has no contact with astronauts when the moon is between them and the earth, so we lost farmers whenever they went into a draw, behind a hill, or into their house. Furthermore, the transmitter contains no mechanism to distinguish electrical impulses related to cardiac activity from those associated with other muscular movement. We found ourselves counting footsteps and machete strokes among our heart beats, not to mention the mammary shiftings of our more buxom cooperators. (This came to be known as "the cleavage problem"; volunteers to remedy it were legion.)

Because biotelemetry makes it possible to monitor physiological functions continuously, it has tremendously expanded our powers of detailed data acquisition. However, this creates a need for suitable data processing instrumentation--instrumentation whose sole function can in some instances be to reduce a mass of instantaneous parameters to manageable amalgams or samples. Such is the case with energy studies where the data sought are not individual heart beats, but averages over a period, or samples.

The absence of equipment to provide such manipulations in 1968 and the great expense that would have been involved in its creation obliged us to make them manually. As Ph.D. candidates flatly refuse to sit up all night counting heart beats from a strip chart recorder and even M.S. students grow restive, this proved the straw that broke the camel's back, and we were forced to abandon biotelemetry in favor of SAMI instruments. These sacrifice the detail of data for the integral of the measurements--e.g., the amount over a period of time--and in so doing overcome many of the limitations of biotelemetry.

SAMI

SAMI stands for Socially Acceptable Monitoring Instrument and in comparison to biotelemetry, with its antenna, it is indeed "socially acceptable" for energy studies (Figure 1c; and Figures 5-8). The devices are small and light enough to fit into a shirt pocket and require a minimum of attention from both the wearer and the investigator.

What makes SAMI run is the E-cell, a tiny electrochemical device which serves as the integrating component. It is housed in a small cartridge (Figure 7) similar to a fuse and is capable of integrating any function that can be represented by a current. Existing SAMIs integrate temperature or heart rate.

The E-cell is best thought of as a miniature electroplating machine composed of two electrodes with an electrolyte between them (Figure 9). One electrode is formed by the silver cup containing the electrolyte, the other by a gold-plated rod mounted concentrically inside the cup and insulated from it. Before use in a SAMI, any silver on the E-cell's center electrode is first transferred to the case by inserting the cell into a small, inexpensive replay machine and passing a current through it. During recording a current related to heart rate or temperature is made to flow through the cell in such a direction that silver is plated onto the gold electrode. According to Faraday's first law of electrolysis the quantity of silver that is transferred is proportional to the current flow. For the heart rate SAMI, the signal conditioning circuitry is designed so that each heart beat produces a standard-size pulse of current which is fed into the E-cell. The silver that is plated on the center electrode remains at the final amount until the E-cell is replayed in the replay machine. During replay, a current is passed through the cell to cause the silver to be replated onto the case. The replay machine measures the amount of silver transferred, which in turn may be related to the average heart rate over the period by the current charge into the E-cell per heart beat.

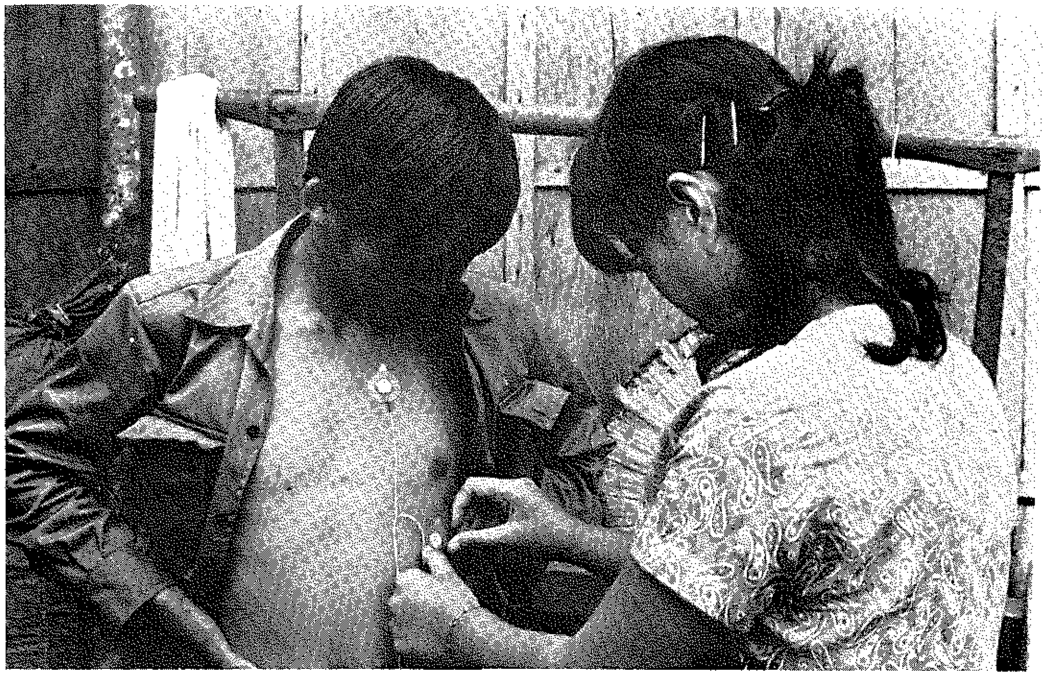


FIGURE 5. (above)
ATTACHING SAMI ELEC-
TRODES TO A FILIPINO
FARMER

FIGURE 6. (left)
TESTING THE PLACEMENT
FOR R-WAVE AMPLITUDE
AND ELECTRODE IMPEDANCE

FIGURE 7. INSERTION OF E-CELLS PRIOR TO MONITORING

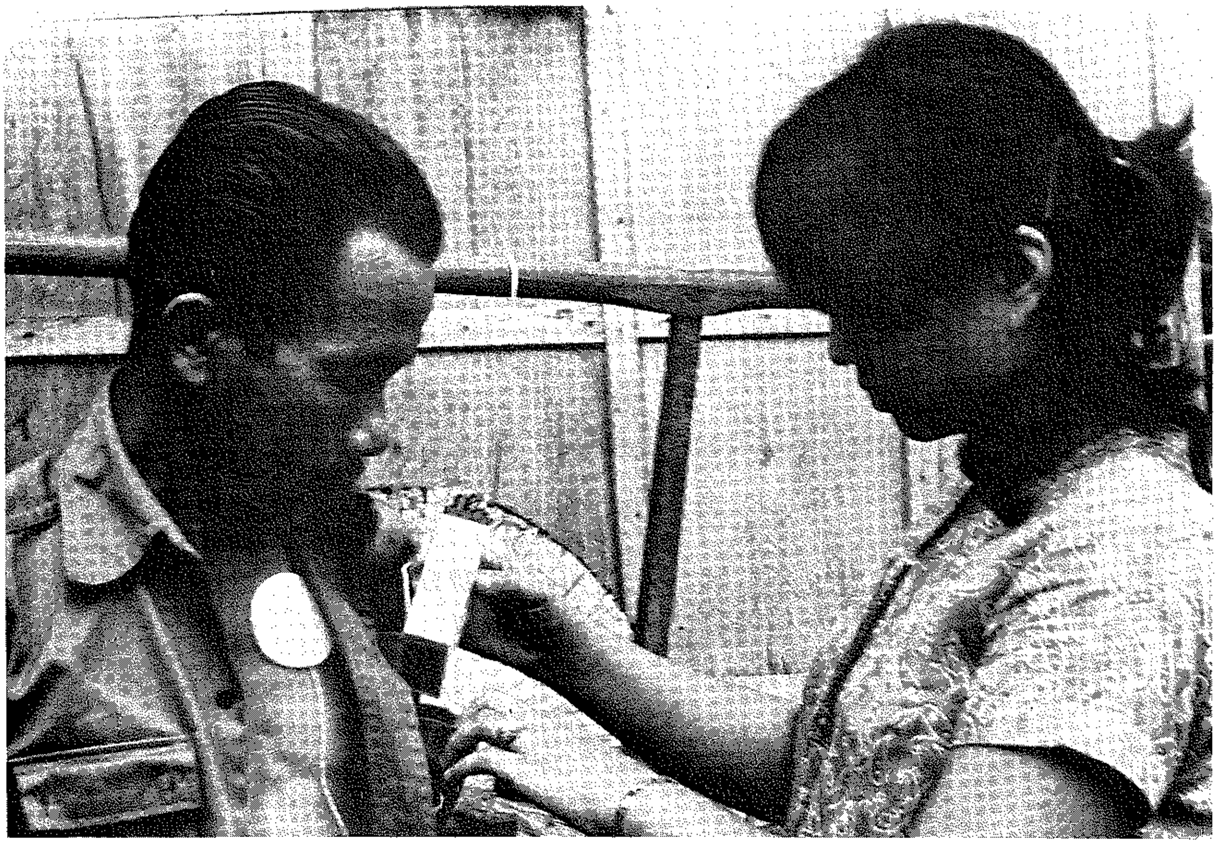
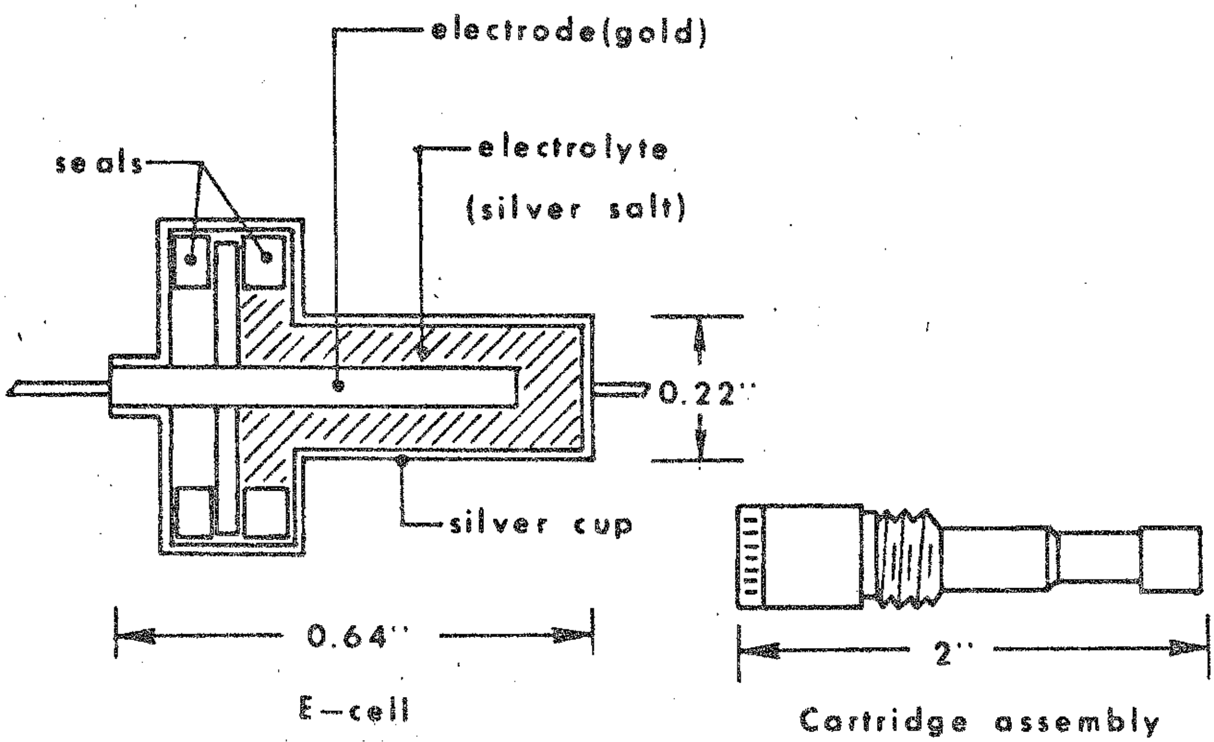


FIGURE 8. POCKETING THE SAMI

FIGURE 9. DIAGRAMMATIC SKETCH OF THE E-CELL AND THE ENCAPSULATED ASSEMBLY



* From 1, p. 27.

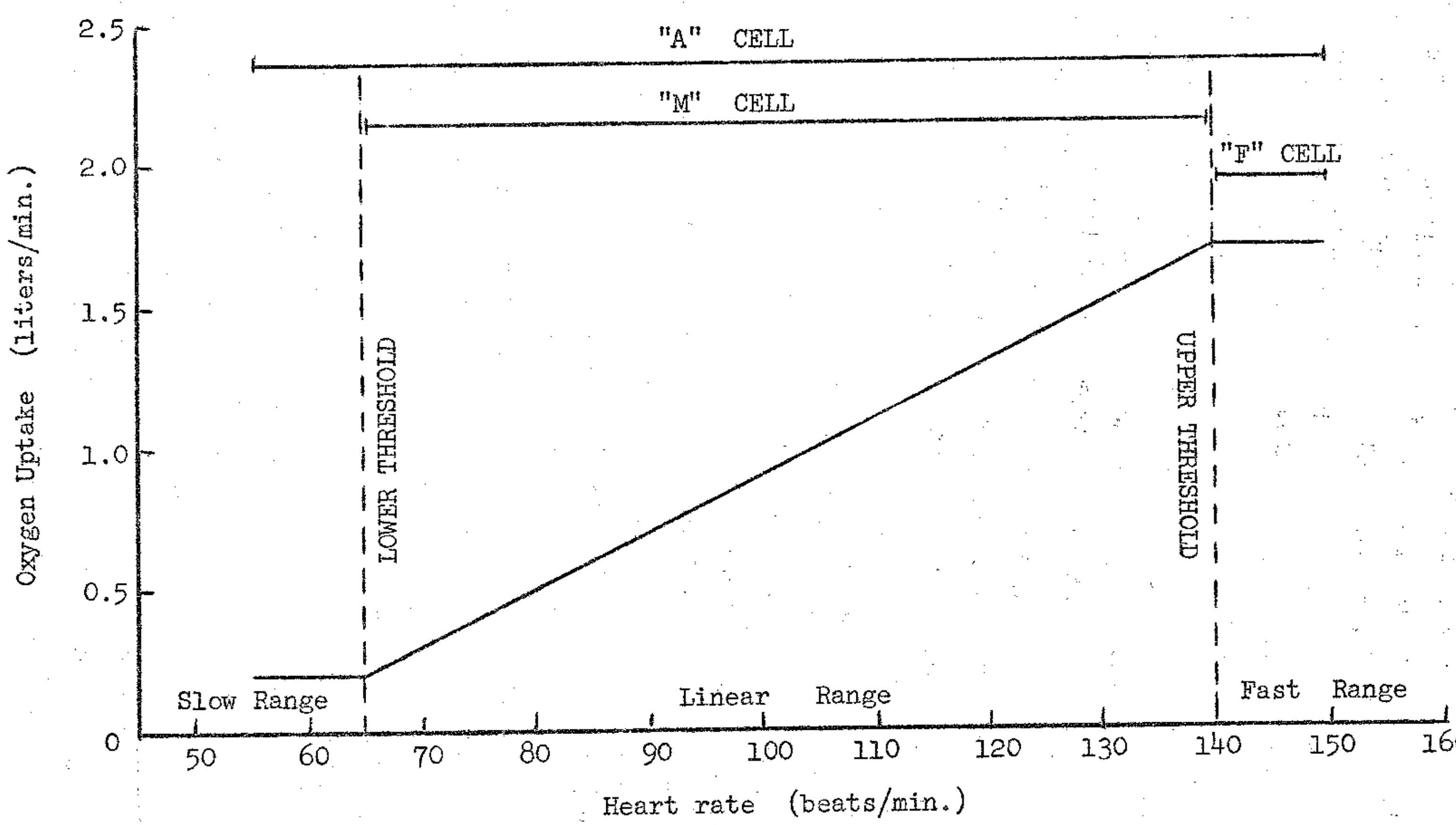
Because the linkage between heart rate and oxygen uptake obtains only over the mid portion of the activity range, energy expenditure work with the SAMI had to await development of a multi-cell unit. These became available in a form suitable for field work in early 1971 and around 15 such units was organized later in the year a major investigation at the International Rice Research Institute in the Philippines.

The results were mixed. The three E-cell SAMI proved highly socially acceptable. Subjects were accurately monitored with it for prolonged periods and went about their activities without physical or psychological impairment to normal behavior. However, reliable predictions of energy expenditure did not in all instances follow. Instead a number of limitations to the notion of simple prediction of energy output from application of heart rate to an individual's heart rate/oxygen calibration slope were revealed.

The oxygen/heart rate relationship and what the three E-cell SAMI monitors is illustrated in Figure 10. Though an oversimplification, it indicates that oxygen consumption does not move with heart rate in the region of resting metabolic rate. Similarly, the relationship breaks down in the upper region where at some point an "oxygen debt" may be expected to occur. The two thresholds are adjustable and by moving them up or down as needed for each individual it is theoretically possible to isolate the beats occuring in these extreme rate ranges from those recorded in the area where linearity obtains. The nature of the linear linkage--the "slope", as we call it--is determined for each individual by simultaneously monitoring heart rate and oxygen uptake at four levels of exercise on a bicycle ergometer (Figure 11).

In the Philippine study we selected ten beats above resting heart rate as the likely point at which the linear linkage would set in--an approximation of the point related to the onset of motor activities. The upper threshold, in practice of little consequence, was uniformly set at 140 beats per minute.

FIGURE 10. SIMPLIFIED HEART RATE-OXYGEN RELATIONSHIP INDICATING REGIONS RECORDED BY EACH E-CELL



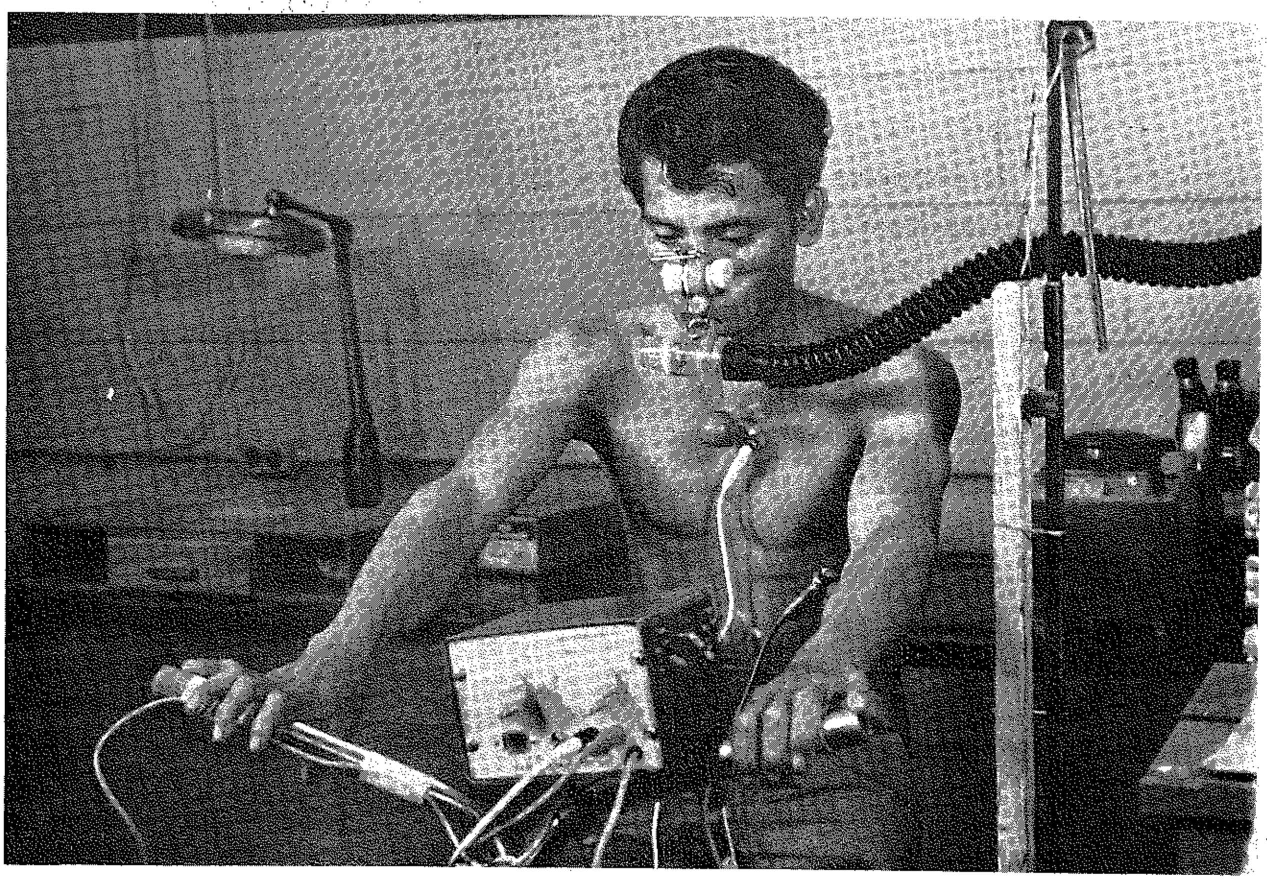


FIGURE 11. CALIBRATION OF A PARTICIPANT IN THE PHILIPPINES PROJECT

The problems we encountered in our attempts to measure energy expenditure with the three E-cell SAMI fell under three headings:

1. Mechanical difficulties with the monitoring instruments.
2. Determining valid resting rates for appropriate threshold adjustment.
3. Shifts in the heart rate/oxygen linkage associated with changes in environmental temperature and work duration.

The last mentioned caused the greatest problems and is the least amenable to simple solution.

One should always expect bugs to appear in new equipment and whether we had more or less than our share is unclear. But bugs we had. Particularly troublesome were the potentiometers which were adjusted daily to change thresholds. Despite the efforts of the manufacturers in England and the technicians of the Rice Research Institute, about a third of our 15 SAMIs were invariably on the sick list.

With respect to the second problem, difficulties in obtaining reliable resting heart rates went far toward invalidating the heart beats recorded in the three rate ranges for which the SAMIs were adjusted.

It is becoming common knowledge among doctors, physiologists, and other specialists that there is no such thing as <u>the</u> resting heart rate for a particular individual. Resting rate fluctuates from day to day and within the day depending on the length and nature of the previous night's sleep, psychic stress, fatigue, and a host of other variables. Generally, resting rate tends to be lowest toward the end of sleep, gradually increasing through the day. But despite this variation, there is a rather narrow band of readings for each individual which can properly be considered the true resting rate.

Determining this rate is not easy, particularly among tropical farmers. Such people are active very early in the day, and it must be considered an imposition to ask them to sit quietly for an extended period so the heart rate can fall to a resting level. There is, in fact, considerable evidence that even such physical quiescence will not satisfactorily reduce heart rate. The excitement generated by visitors to the barrio, the demands of small children and animals, and the general anxiety caused by actually taking the pulse all conspire to give abnormal readings. These readings were translated into inappropriate threshold adjustments and resulted, in more instances than I like to recall, in E-cell readings which made no sense.

The SAMI has recently been modified to lessen dependence on an accurate resting rate. As illustrated in Figure 12, the SAMI modified to the Garrow specifications has the "A" cell collect all beats as before, but alters the responsibility of the "F" and "M" cells. "F" collects all beats above the lower threshold (adjustable from 70 to 120 beats), while "M", acting as a timer, monitors the total minutes in this range. In this way we can know (rather than derive) the actual minutes spent in the slow range and the linear range as well as the number of heart beats in each. Thus the average rates in the linear and sub-linear cells can be computed with precision. In the process the upper threshold is eliminated; this is hardly a significant loss.

This improvement in the capabilities of the SAMI does not, however, enable us to come to grips with the principal difficulty we encountered: a shifting in the linkage between heart rate and oxygen uptake with changes in environmental temperature and work duration.

Whereas calibration was performed in an air-conditioned, dehumidified room with liberal rest periods, the tropical farmer's day-to-day existence depends upon his willingness to work under a hot sun, often for fairly long stretches of time. Research indicates that the heat load imposed by a warm environment and extended exertion will increase heart rate faster than oxygen consumption, altering the relationship established under less trying conditions (2, p. 277). The effect can be seen in Figure 13, taken from a study by LeBlanc among military personnel. Here we observe that heart rate rises slowly with increasing temperature. That the calibration slopes themselves shift was demonstrated by Winterhalder and Poleman among U. S. Army reservists in

FIGURE 12. SIMPLIFIED HEART RATE-OXYGEN RELATIONSHIP INDICATING REGIONS RECORDED BY EACH E-CELL: GARROW MODIFIED SAMI

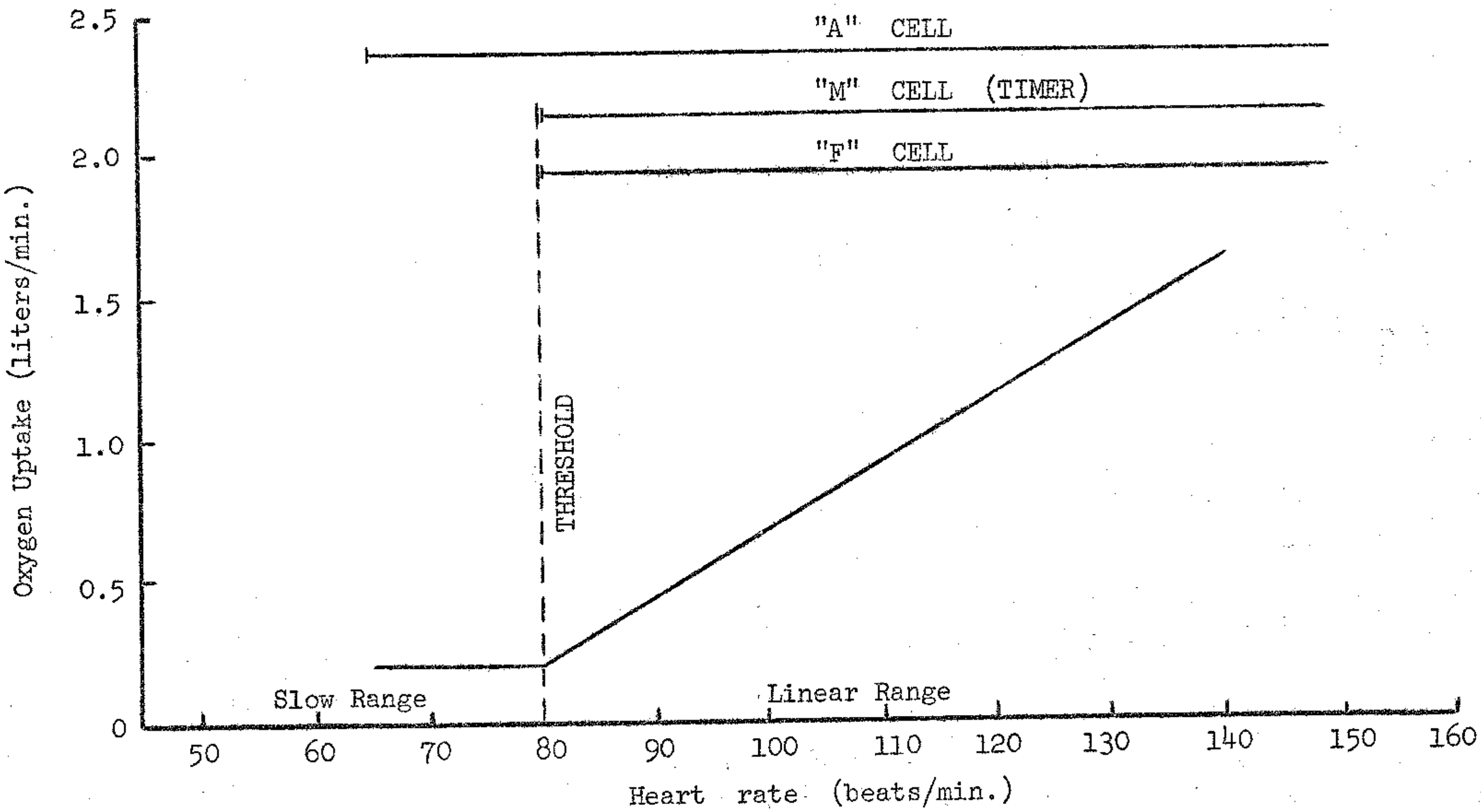
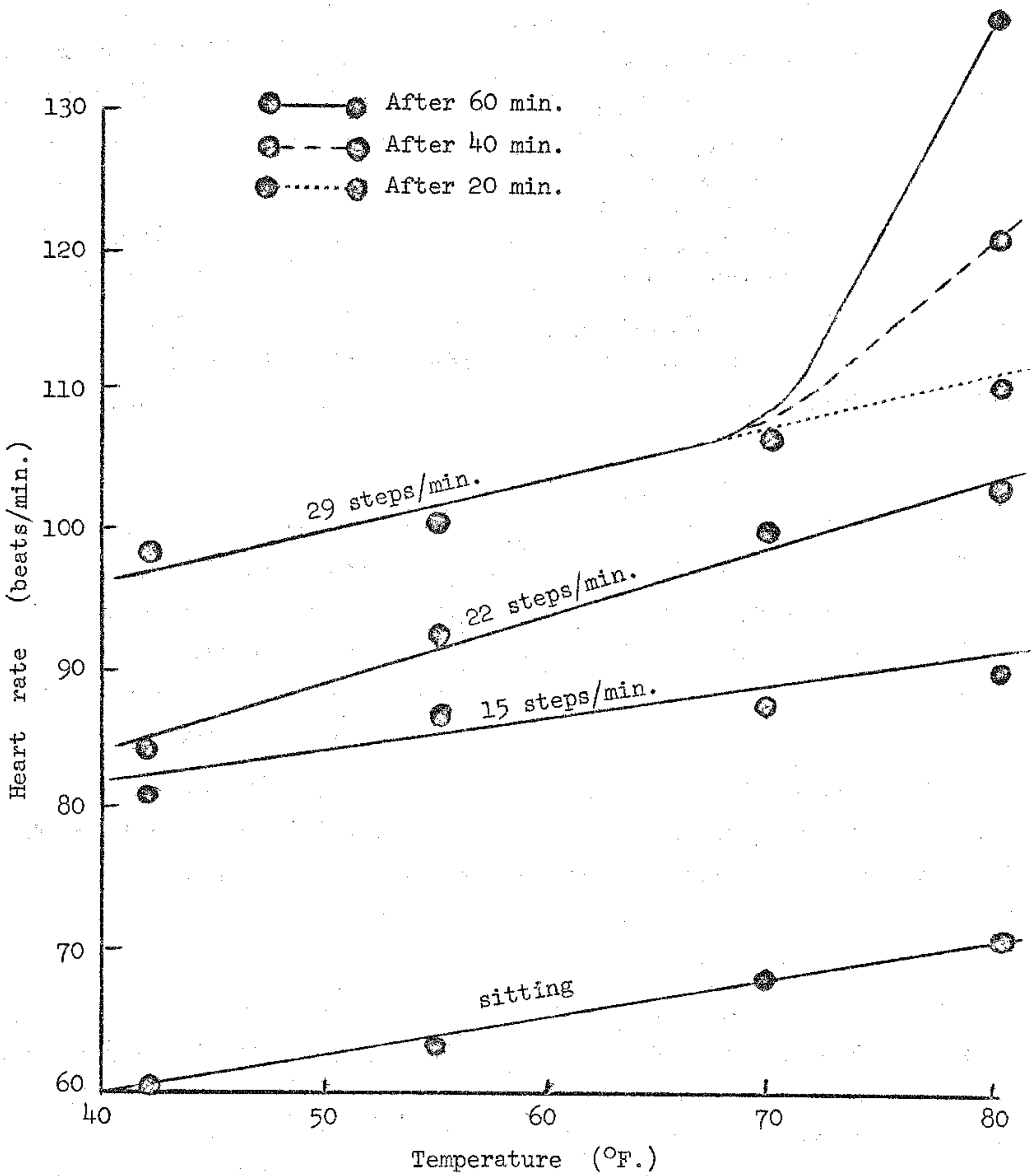


FIGURE 13. EFFECT OF AMBIENT TEMPERATURE AND PROLONGED EXERTION ON HEART RATE (Subjects exercising at different rates on a six-inch platform)*



*From LeBlanc, "Use of Heart Rate as an Index of Work Output," Journal of Applied Physiology, Vol. XXVI, No. 3, 1969 (p. 277).

May 1972. Even more damaging, however, is the effect of prolonged exertion. At moderately high levels of exercise the heart rate increases sharply after 20 minutes, becoming more and more estranged from the calibrated relationship.

If heart rate is to yield meaningful predictions of energy expenditure other than under laboratory conditions, in other words, more must be taken into account. A time dimension is needed, as are data on heat and perhaps other parameters.

Happily an alternative to biotelemetry for collecting this sort of detailed physiological information has become available within the last few months. Also developed by Heinz Wolff and his associates at Britain's Clinical Research Centre, this newest member of the SAMI family is designated the SATR. A Socially Acceptable Tape Recorder! (Figure 1d.)

SATR

In fact two multi-input miniature tape recorders have recently been created at CRC: one designated the MEDILOG by its inventor, Dr. F. D. Stott, which like biotelemetry monitors continuously and which was designed with the needs of the cardiologist chiefly in mind; and the SATR, whose time dimension is the systematic sample and whose applications lie more with the physiologist and the social scientist.

The SATR is actually a SACR, since recording is made onto a miniature Philips cassette; but whoever heard of a SACR pursuing nubile nymphs through the forest? Inputs exist for three data tracks and a time control track. With time sharing each data track between two inputs, a six-channel capability is possible.

By sampling each input for 100 milliseconds at one-minute intervals, it is possible to record about 36 hours of data on the 15-minute cassette. The timing mechanism is both intriguing and simple. An ordinary watch mechanism is used to trigger a bistable flip-flop to turn on the electrical drive-motor. Once a minute the second hand interrupts a light beam which is focused on a photocell and this triggers the bistable circuit. Power comes from an 8.5 volt mercury cell.

During this period, the mercury cell also powers the signal conditioning circuits. The signals from the conditioning unit are analog voltages somewhere between 0 and 1.5 volt. When the tape starts moving, a square-wave oscillator generates 1-millisecond pulses. These pulses go directly through three parallel gates to the three data tracks on the tape, and through a fourth output into a staircase generator, which effectively integrates them in 15-millivolt steps. Thus, this generator divides the analog range of 0-1.5 volts into 100 steps. While a gate is open, oscillator pulses are recorded on the tape until the gate is closed by the staircase generator output reaching the analog input signal level. Therefore the number of pulses on the tape is proportional to the input signal level.

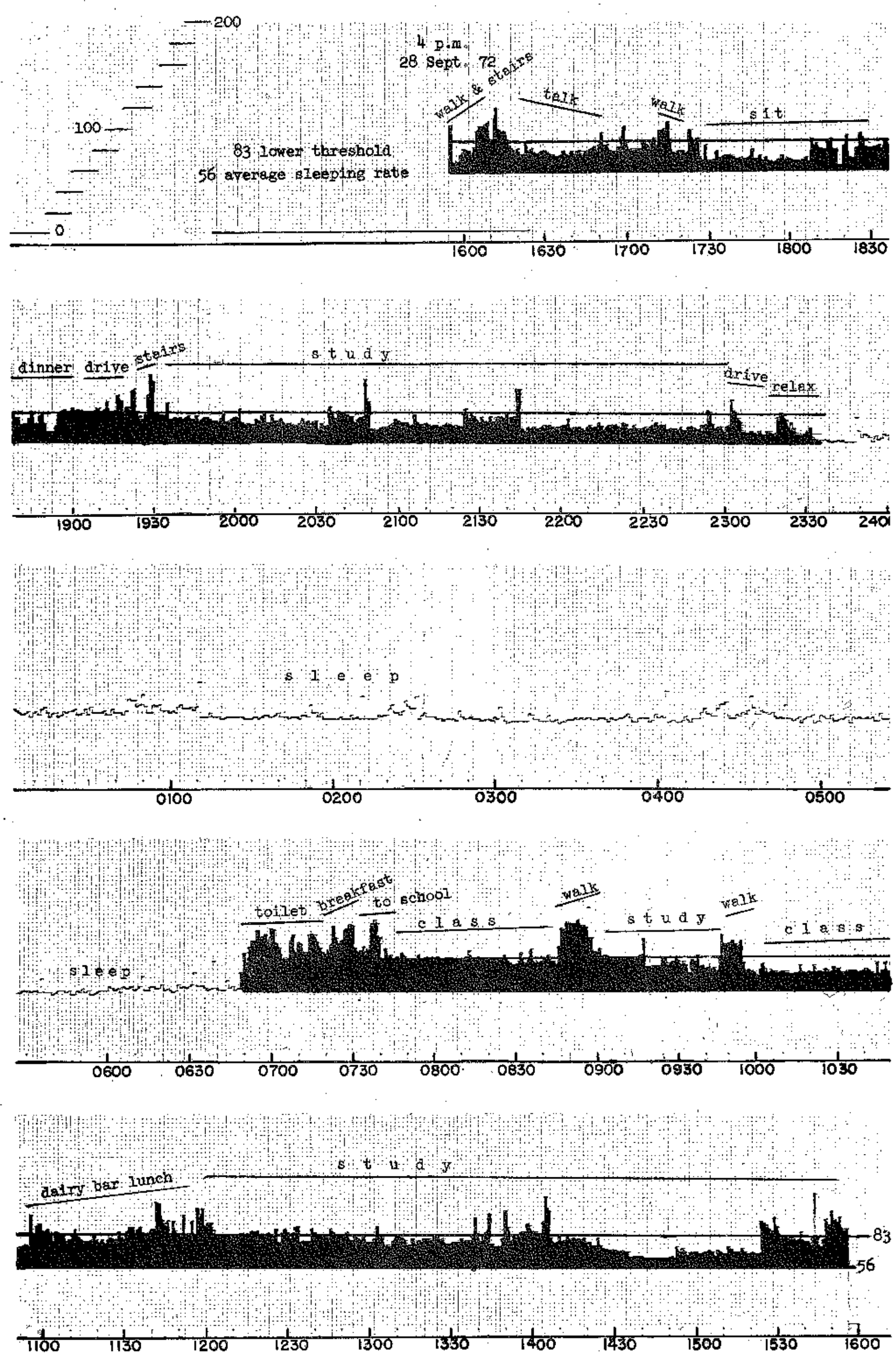
During the first 50 pulses, the staircase generator is building up to the level at which the gates open. Thereafter, it feeds three parallel comparators, which are also fed by the analog signals. A gate closes when its comparator gives an output. Thus, the accuracy of the analog-to-digital conversion is $\pm$ 15 mv or 1% of full scale, plus perhaps another 1% lost in measuring tolerances.

The SATR replay unit can produce either analog tracings, punched paper tape, or digital incremental tape. The first (Figure 14) is ideal for visual analysis and graphic presentation, while the punched tape is appropriate for direct computer analysis.

Because of its multiple inputs and time-discrete monitoring capabilities, the SATR holds promise of shortly permitting us to determine the energy expenditure of free-ranging man. Trials carried out in the spring and summer of 1972, respectively among soldiers at Fort Sam Houston and grass cutters on a dairy farm in Ceylon, suggest that simultaneous monitoring of heart rate, skin temperature, and ambient temperature may permit us to "deflate" for those heart beats unassociated with energy expenditure.2/

2/ Other inputs will shortly be available for: ventilation volume, posture (18 variations), and oxygen content of expired air.

FIGURE 14. A SATR ANALOG TRACING OF A DAY IN THE LIFE OF A CORNELL STUDENT



Note: The range on the chart is 0-200 beats per minute. Sampling frequency is once per minute. Average sleeping rate is 56 bpm and the lower threshold of heart rate-oxygen linearity is taken as 83 bpm. The tape is shown slightly reduced in size.

Indeed, by combining the advantages of the E-cell SAMI with the continuous or sampling features of biotelemetry, the SATR opens up possibilities for a number of research applications, and it is to these that we turn. In presenting them I will speak as an economist and as an economist interested in the less-developed countries (LDCs).

II. ECONOMIC APPLICATIONS OF VITAL-RATE MONITORING

The principal applications we have considered are summarized in Figure 15 and fall under two headings: food and employment.

Food Area

I have already noted that I was first led to vital rate monitoring by a desire to quantify the calorie requirements of human populations. This seemed a reasonable aim in 1968. Food was thought to be in short supply in many of the developing countries, and for food policy planning to proceed logically quantification of needs as well as availabilities seemed in order.

Today this is less a priority target. The limited application of the scientific method to food production in the LDCs has caused a dramatic shift in the nature of the problems they face. Most observers now perceive that applied technology in agriculture has only scratched the surface, that, given reasonably honest and effective governmental administration, production almost everywhere can keep well ahead of (declining) rates of population growth; that whatever individual food problems which may persist will be best interpreted in terms of employment or income; and that it is to questions of employment and income that research should be focused.[3/]

Yet this does not mean that quantification of calorie requirements should be discarded as a research objective. It can be got as a by-product in employment studies, and human food needs remain of more than just intrinsic interest.

3/ Let he who doesn't believe it see 3.

FIGURE 15. APPLICATIONS OF VITAL RATE MONITORING

Food Area

(Calorie taken as measure of energy; inferred from heart rate)

1. National or individual calorie needs.

   Original research aim, but now by-product of other objectives. Assumes activity not restricted by shortfall in food intake, a not unreasonable assumption. Perhaps most relevant to developed countries; here problem is of overfeeding and underactivity. But may still be useful in LDCs --see Figure 16.

2. Economic cost of undernourishment.

   Application limited: for undernourishment to have cost to society full employment must be assumed; with full employment there is rarely a food problem. Usefulness probably confined to measuring impact on effort of food intervention programs.

Employment Area

(Calorie--or percent increase over resting rate--taken as common denominator of the factor of production labor, with time inferred according to local man-day customs; inferred from heart rate)

1. Quantification of existing patterns of human activity.

   Using SATR and diary:

   a. Determination of local man-day norms.
   b. Work/leisure trade-off.

2. Evaluation of effect on employment of alternative investment strategies.

   a. Effect on factor input of changed economic environment, presumed to enhance output.
   b. Determination of relative factor inputs associated with alternative means of accomplishing same task: to be employed in budgeting exercises aimed at enhancing factor input, output, and ameliorating bottlenecks.

3. Treating symptoms of unemployment.

   Psychological cost of alternative activity situations may be suggested by simultaneous monitoring of several physiological parameters. (Perhaps not science, but not necessarily fiction.)

This is particularly true in the urbanized, developed countries of the West. Here major problems loom from overfeeding and underactivity. Inspect first your waistline, then Figure 14. For the young man monitored therein motor activities--those which involved him moving about--are related to a heart rate in excess of about 83 beats per minute. The tape suggests that such activities were engaged in during only about 200 of the day's 1440 minutes. One suspects many other urban dwellers find their lives equally untaxing physically, and it does not strain the imagination to conceive of **artificial** stressing being consciously introduced to prevent premature heart problems becoming endemic. In the meanwhile it is well to recognize the problem and forego that extra Martini or cupcake.4/ Where lies the economics? I suspect with the planners of our next round of cities, offices, factories, and life styles.5/

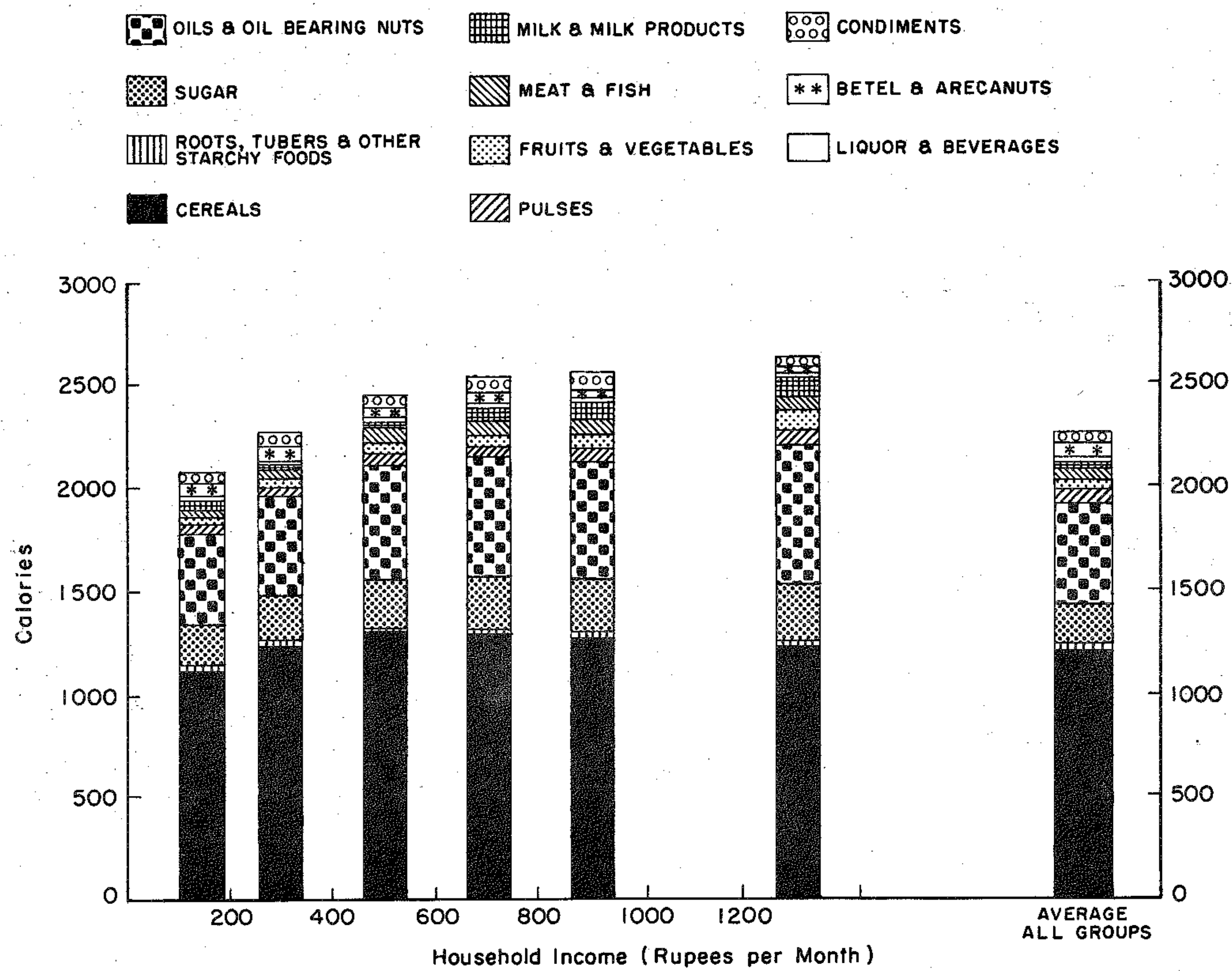
But if the principal "food" applications of vital-rate monitoring are in the advanced countries, it does not follow that there are no longer uses in the LDCs. Consider Figure 16--an uncommonly detailed and reliable indication of the effect income has on the dietary of the people of a relatively poor country. The usual experience and expectation is for substantial changes in diet quality to take place as one becomes wealthier: fewer cereals and other starches are customarily eaten, their place being taken by greater quantities and more preferred types of meat, vegetables, milk, eggs, and the like. In Ceylon this tendency is observable among only the four uppermost income classes (20 percent of the population) and then only weakly so. Between the lowest class (43 percent of the people) and the next lowest (37 percent) the sole change is quantitative. Between the classes there is a difference in apparent per capita daily availabilities of 200 calories, but none in diet composition.

What does this mean? Because per capita calorie needs in Ceylon are reckoned to be of the order of 2100 calories per day, it could mean either of two things. The 200-calorie gap could be interpreted as implying

4/ Calorie-wise the two are interchangeable: nutrition pretends to science not art.

5/ This problem, and possible solutions, was first discussed by Professor R. Passmore in a prophetic report to FAO (4).

FIGURE 16. CEYLON SOCIO-ECONOMIC SURVEY 1969/70: APPARENT PER CAPITA DAILY CALORIE CONSUMPTION, BY FOOD GROUPS AND INCOME CLASS



*From 5, p. 17.

enforced reduced activity among the poor and/or actual physical deterioration. Alternatively, it could be interpreted as reflecting less food wastage among the poor or perhaps--if, as is the case with so many in Ceylon, they are not employed--lower calorie needs growing out of less active lives. A study of energy expenditure could tell us which is the correct interpretation.

One other "food" application of vital-rate monitoring in the developing world warrants mentioning. I have included the "economic cost of undernourishment" in Figure 15 because several friends in FAO's Nutrition Division have suggested or asked about it. The argument in its support is essentially a variation of the "hunger-breeds-hunger" line of reasoning enunciated in 1946 by FAO in its World Food Survey (6): that is, of inadequate diets causing poor physiques and lowering potential energy output to such a point that people are physically unable to produce more food. Because the pre-harvest hunger phenomenon of the sub-Saharan savannah comes when people should be harvesting--runs the line--they don't harvest, thereby depriving themselves and society.

There are a number of reasons why I find this reasoning fallacious, but, the literature on pre-harvest hunger aside, for undernourishment to have a cost to society a full employment situation must be assumed. And with full employment, food problems are rare.

A more valid extension of this "nutrition determinism" type of reasoning would be to attempt to measure the impact of food supplementation schemes on energy output. Such schemes are called for in LDCs when people find themselves in employment situations to which traditional eating habits have not yet accommodated. But it is questionable whether energy output would better reflect the benefits of, say, a hot lunch scheme in a factory canteen than would the increase in the volume of production.

Employment Area

In the food area, applications of vital-rate monitoring require considerable manipulation of the physiological parameters before a meaningful statistic--the calorie--emerges. This need not be the case in employment studies. The calorie may well be taken as the measure of inputs of the factor of production labor. But there is no reason why it need be the only one. Many tasks are more exhausting emotionally than physically. For them the labor input might better be reflected by total heart beats--whether caused by emotion, exertion, fatigue, or heat stress--related, so individual variations could be smoothed over, to sleeping rate.

Here is an area where we have to be innovative. We are dealing with a new data source and there is no reason why we need hamstring it with measurements or common denominators of the past. Empirical economics builds on the gettable, and the more readily gettable the better. Why try to count the number of glasses of milk consumed daily in New York City if an indication of the same can be derived from marketings?

The several applications of vital-rate monitoring to employment studies listed in Figure 15 take as their point of departure the assumption that providing jobs for growing populations will be the chief problem facing LDCs in the decades ahead and that considerable scope for employment generation lies within the agricultural sector. The validity of the second assumption is less certain than the first and we will return to it. Still an examination of the impact on employment of technical change within agriculture is clearly desirable.

Traditional tools for doing this are few, and understandingly so. Research in the field of farm management has aimed not at maximizing the factors of production but the returns to them. To have done otherwise would have been quite silly until very, very recently. Imagine the reaction in New York State to research designed to maximize the number of people milking cows! Only within the past few years has the need existed for imposing full-employment constraints in the formulation of agricultural planning models.

In part for this reason our knowledge of the precise inputs of labor associated with various agricultural tasks is minimal. In part our ignorance also stems from the difficulties associated with the traditional methods for quantifying labor. Because of problems of conceptualization as well as measurement--e.g., culture specific man-day norms--this has typically in the LDCs involved use of the time-motion technique. This technique is quite appropriate to industry, but not to agriculture. In effect the invetigator has to spend virtually all his time with a handful of subjects throughout the agricultural cycle--a very expensive and time-consuming operation if a statistically meaningful sample is to be surveyed. The upshot is that our understanding of the inputs into even paddy production is deficient.

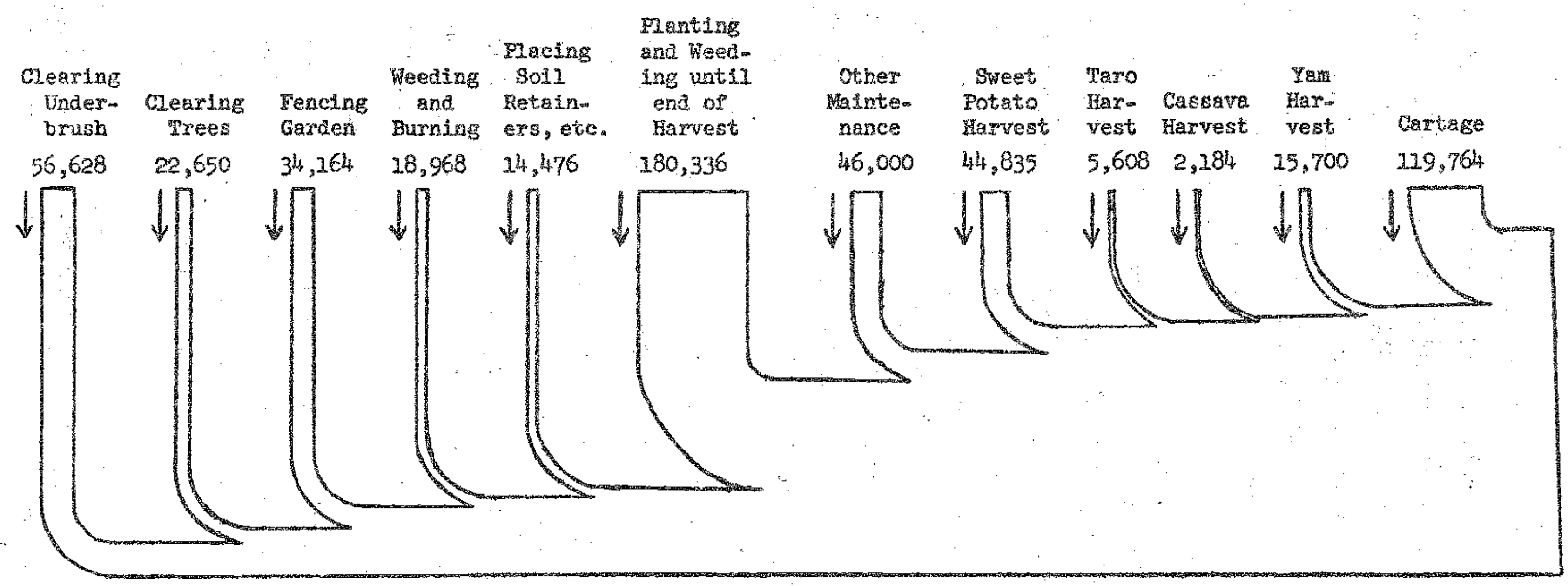
The approach to labor quantification followed in our Philippine study, and proposed for others, is essentially two-pronged. An appreciation of the labor inputs associated with existing agricultural systems is got from monitoring a number of farmers throughout the agricultural cycle. Had we not confronted the problems that resulted from heat and durational stress, what would have emerged would have been pictures of the labor inputs associated with four agricultural systems similar to that illustrated in Figure 17 for New Guinea yam gardening.[6/] Immediately identifiable would be any points at which labor constrained the size of operation--where introduction of a labor-saving device might increase employment--and an appreciation of local work norms and some idea of the extent of unemployment and underemployment.

The other "prong" of our approach seeks to build up the kind of data needed to predict the effect on employment of alternative investment strategies. Here our aim is to derive--from small though, because use of the calorie or physiological common denominators allows us to tide over problems of individual variations, statistically meaningful samples--the labor costs associated with alternative means of performing the same task. From a backlog of such data budgeting exercises could be initiated which could aim at enhanced factor input as well as output. Examples of the types of comparisons which were attempted in the Philippines are given in Figure 18.

6/ The data in Figure 17 are in part hypothesized. The research on which they draw used respirometer-type devices for estimating energy expenditure.

FIGURE 17. ENERGY INPUT INTO YAM GARDENING IN NEW GUINEA*

(Calories per acre)



* From 7, pp. 120-21.

FIGURE 18. ENERGY MEASUREMENT TARGETS FOR SPECIFIED TASKS IN RICE PRODUCTION

Task	Operation Alternatives	Data to be Measured
Plowing	1. Tractor 2. Carabao	Cal./hectare
Harrowing	1. Tractor 2. Carabao	Cal./ha.
Planting	1. Manual transplanting (dapog) 2. IRRI row seeder 3. Broadcast seeding	Cal./ha.
Weeding	1. Manual 2. Hand rotary 3. Power rotary 4. Herbicide	Cal./ha.
Harvesting	1. Sickle 2. Hand drop manual harvester	Cal./ha.
Threshing	1. Manual 2. Hampasan (frame) 3. Pedal thresher 4. IRRI table thresher	Cal./ton rice
Winnowing	1. Manual 2. Native winnower 3. IRRI hand winnower	Cal./ton cleaned grain

Though studies aimed at deriving factors for labor-use budgeting should be pressed with priority in the LDCs, it would be a mistake to expect them to reveal easy solutions to the unemployment dilemma. A few paragraphs back I expressed reservations about the scope for employment generation in agriculture. Most of the components of the Green Revolution, after all, are capital-, not labor-, demanding. And economic progress has historically been associated with a decline, not a rise, in the absolute and relative importance of agriculture as an employer.

Coupled with the well-known difficulties of creating an industrial sector that is anything but capital intensive in economies which are open to international competition, this means we had best begin to think in terms of treating the symptoms, as well as the causes, of unemployment. Were I asked what the greatest social adjustment the LDCs were going to experience in the decades ahead, I would unhesitatingly answer: "Making do with nothing to do." While the quality of life in these countries will doubtless significantly improve on the average over the years, barring political upheaval, I do not see how rising numbers of welfare recipients can be avoided.

How can this be made most palatable? The Protestant Ethic of the West, associated with 200 years of economic dynamism where the opportunities existed, has work as its own reward. Would one imbued with this code respond to a life of forced economic idleness in the same way as would, say, an unemployed Ceylonese whose Buddhist culture draws on 2000 years of semi-stagnation and the constraints to individual freedom imposed by paddy rice cultivation? The evidence conflicts. It is difficult to conceive of the unemployment rates which characterize Ceylon being tolerated in the West. But when in the spring of 1971 they rose in bloody rebellion against a system which offered security but few opportunities, the young, educated unemployed of Ceylon gave evidence of the work ethic being more than a product of the Industrial Revolution. And the pot smokers of Harlem seek an escape from their trials in a manner not unlike that suggested by Lord Buddha.

Psychophysiology is a young science. Some would argue it is not a science at all. But a growing body of data is accumulating which suggests that emotional state will be reflected in monitorable physiological parameters. The thing of course is individual; no two people react identically to a polygraph test, and some can out-fox it. But it is not unreasonable to expect that, say, heart rate and galvanic skin response--both now easily measurable--would in concert give an indication of the direction of an individual's response to alternative environmental circumstances.[7/]

It may not be science, but I suspect it's not altogether science fiction. There are a number of explanations of why the "bread and circuses" of ancient Rome ultimately failed to buy off the citizenry. One, I suspect, was that the same sop was offered to all. Perhaps the most valuable application of vital-rate monitoring will be to enable us to differentiate.

On this rather speculative note I take leave of the serene South Seas and return you to reality and the grime of New York.

7/ See 8 for the sort of parameters that may be meaningfully monitored.

CITATIONS

1 T. T. Poleman, Weyland Beeghly, Peter Matlon, and Andrew McGregor, "The Economic Applications of Vital-Rate Monitoring" (Cornell International Agric. Dev. Bulletin 38, November 1972).

2 J. A. LeBlanc, "Use of Heart Rate as an Index of Work Output"" Journal of Applied Physiology, Vol. X, No. 2, 1957.

3 T. T. Poleman, "Employment, Population, and Food: The New Hierarchy of Development Problems" Food Research Institute Studies, Vol. XI, No. 1, 1972.

4 Food and Agriculture Organization of the United Nations (FAO), "An Assessment of the Report of the Second Committee on Calorie Requirements (FAO, 1957)" (1964).

5 T. T. Poleman, "Income and Food Consumption: Report to the Government of Sri Lanka" (UNDP and FAO Report No. TA 3198, Rome, 1973).

6 FAO, World Food Survey (Washington, 1946).

7 R. A. Rappaport, "The Flow of Energy in an Agricultural Society" Scientific American, September 1971.

8 P. H. Venables and I. Martin, A Manual of Psychophysiological Methods (Amsterdam, 1967).