EXPERIMENTAL STUDIES OF TOOL EFFICIENCY AMONG MACHIGUENGA WOMEN AND IMPLICATIONS FOR ROOT-DIGGING FORAGERS

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Experimental measurements of the efficiencies of traditional wooden versus modern metal tools among Machiguenga women of the Manú River Basin indicate that individuals using wooden tools spend two to three times as many minutes digging and peeling one kilogram of manioc as they spend when using machetes and knives. However, because Machiguenga women can acquire enough manioc in one hour to feed twenty-five adults for one day, a two- to threefold adjustment in the time spent digging and peeling with traditional tools to compensate for lower efficiency leads to only a minor difference in the absolute time spent daily in subsistence tasks. On the other hand, the adoption of metal tools by indigenous women may lead to important changes in women's time allocation to subsistence work and their dietary contribution when root digging and peeling rates are significantly lower than the ones found among Machiguenga women; for example, in foraging societies dependent upon wild tubers. This study shows that experimentation is a useful tool for measuring and predicting the effects of modern technology on the sexual division of labor across ecological contexts.

THROUGHOUT HUMAN HISTORY the introduction of new food procuring, producing, and processing technologies has led to changes in subsistence behaviors, demographic trends, and social organization (see Cohen 1977; Clark 1952; Ember 1983). These changes spread very quickly due to the improvements in efficiency that new technologies offer. Given the marked sexual division of labor in humans, technological introductions are likely to affect the sexes differentially. Specifically, increased subsistence efficiency may radically alter the dietary contribution of one sex versus the other and the number of hours spent in subsistence tasks by one sex versus the other.

Despite this, most studies of the effects of technological adaptations on subsistence behavior in preindustrial societies have only measured men's efficiency as a function of tool type. In the specific case of lowland South America, the effects of modern technology on male productivity can be substantial and may produce significant changes in hunting strategies and in the location and size of sites cleared for planting (Carneiro 1970, 1979a, 1979b; Saraydar and Shimada 1971; Yost and Kelley 1983; Hames 1979, 1984; Hill and Hawkes 1983; Saffirio and Hames 1984; Kaplan 1985).

The effects of modern tools on female productivity have received relatively little attention, partially because women have continued to use traditional tools in many remote areas. Nevertheless, knives and machetes have become important substitutes for the wooden implements used by most indigenous groups for harvesting and processing roots. This paper presents the results of experiments designed (1) to compare the relative efficiency of wooden and metal tools used to harvest and process sweet manioc in order to assess the extent to which metal tools may have produced changes in female subsistence behaviors among the Machiguenga in recent times and (2) to specify the ecological conditions under which metal tools might have an important effect on indigenous women's work effort.

BACKGROUND

The present study was conducted at the village of Tayakome, located within the boundaries of Manú National Park in southeastern Peru (Hurtado, Hill, and Kaplan 1987; see Johnson 1975 and Montgomery and Johnson 1977 for studies on the Machiguenga of the Kompiroshiato River).[1] This village is currently inhabited primarily by Machiguenga whose parents and great-grandparents lived in various scattered settlements along the headwaters of the Manú River and its tributaries. Since 1980 a bilingual Machiguenga teacher sponsored by a Catholic mission several days downstream has been teaching primary school to the children and to a few adults of Tayakome. Aside from this outsider, the community currently experiences very infrequent contact with other Peruvians.

The population of Tayakome depends on gardening, hunting, and collecting for its subsistence (Hurtado, Hill, and Kaplan 1987). Among the Machiguenga of Tayakome, the main carbohydrate staple, especially in the dry season, is sweet manioc. During the wet months, bananas and plantains are harvested in large quantities. Other plants are cultivated to a much lesser extent (e.g., yams, corn, peanuts, and sugar cane). This diet of manioc and bananas is complemented with fish and game throughout the year.

As is typical of many lowland South American horticulturalists, the sexes divide garden work: the men tend to do more of the clearing and planting, while the women do more of the harvesting and food processing. Time allocation data show that while men spend most of their time fishing or hunting, sweet manioc harvesting and processing are the most important subsistence activities among Machiguenga women and girls during the dry season. Because manioc fields are usually located at some distance from the houses, a large component of harvesting consists of travel time.

Traditionally, Machiguenga used broken palm wood bows for digging sweet manioc roots and flat wooden spoons for peeling the manioc and for cutting the roots into small pieces for boiling. Although the women and girls now prefer to use machetes and knives, these are not always available, so all women have experience using both traditional and modern technology. This allowed us to measure the effects of technological change on harvesting and processing rates.

METHODS

Time allocation and food production data on fourteen Machiguenga women were collected between the months of June and August, 1986, at the Tayakome settlement. These are the driest months of the year in Manú Park, and sweet manioc is the main carbohydrate staple during this time (Hurtado, Hill, and Kaplan 1987). The Tayakome settlement was divided in half for sampling purposes. The women in each half were monitored every other day. Time spent in the acquisition of food was monitored by recording the leaving and returning times of women at a household cluster. All food brought back was weighed with a Hom's spring scale. On several occasions Hurtado followed women to the fields while Hill stayed at the household cluster to monitor subsistence and childcare behaviors of the remaining individuals.

In order to collect data on the efficiency of different tools, Hurtado asked individual Machiguenga women on twelve different occasions (see Table 1, below, cases 1–7 and 1–5) to dig or to process sweet manioc with introduced metal and with traditional tools (bows and wooden spoons). The ages of the women chosen for the experiment ranged between approximately fifteen and fifty years. The women were followed to the fields they had chosen for the experiment. They also picked the individual plants. These were always part of a manioc patch subject to intensive harvesting during that week or month. In order to control for patch quality and individual harvesting abilities, Hurtado asked the women to dig the roots of two plants at the same location: one with a broken bow and the other with a machete. Time spent acquiring the roots was monitored with the use of an electronic wristwatch, and after the roots of each plant were dug, the sweet manioc was weighed.

The processing experiment took place in Machiguenga huts where women do all food preparation. The procedure consisted of asking women to peel and cut equivalent weights of sweet manioc with a knife and a wooden spoon. These activities were timed with an electronic stopwatch.

In order to test for differences, we paired observations on each woman's performance using metal and traditional tools during each experimental digging or processing event and performed paired one-tailed t-tests on the data set.

RESULTS

Technological Efficiency

Analyses show that metal tools have a positive effect on Machiguenga women's productive efficiency (Table 1). First, while women acquire a mean of 168 kilograms of sweet manioc per hour spent digging with a machete, they only acquire a mean of 83 kilograms per hour spent digging with a broken bow (mean difference = 85 kg; SD = 11; n = 5 pairs; p = .0015). Second, the amount of sweet manioc that can be peeled and cut per hour with a wooden

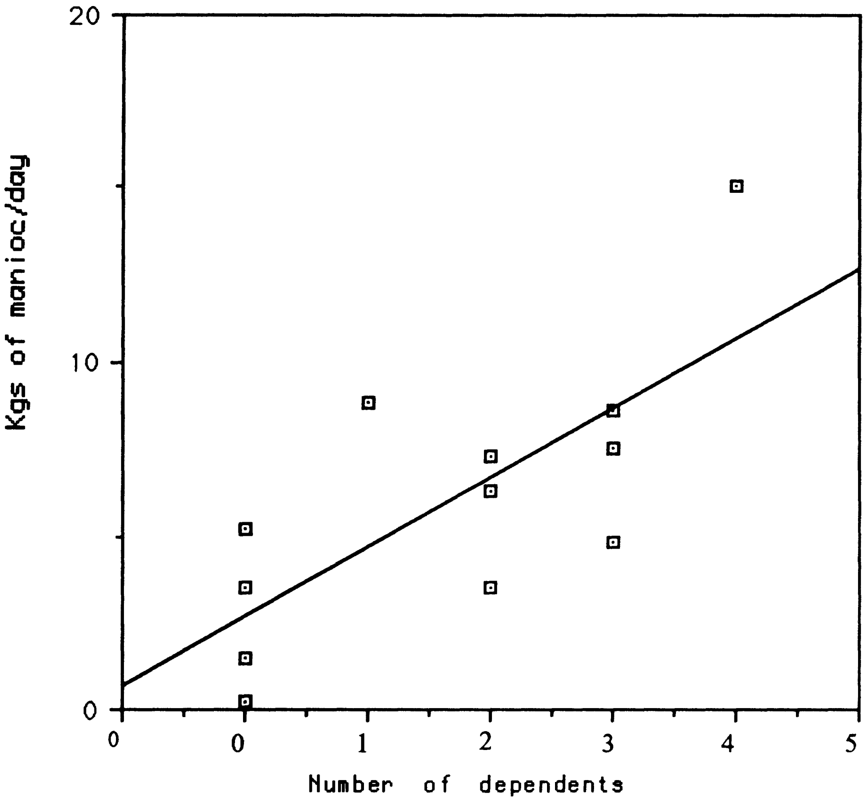

Figure 1. Kilograms of Manioc Acquired per Day by Machiguenga Women Plotted as a Function of the Number of Dependents a Woman Has

$r = .72$; $p = .01316$; $n = 12$ women

spoon (mean = 25 kg; *SD* = 12.1) is significantly less than the amount that can be processed by peeling and cutting manioc with a knife (mean = 66 kg; *SD* = 19; mean difference = 41 kg; *SD* = 23; $n = 7$ pairs; $p = .00003$).

Time Allocation

Experiments designed to test for differences in the number of kilograms of manioc that can be harvested and processed with the use of metal and traditional tools show that Machiguenga women can dig and peel the same amount of manioc with metal tools in half to a third the amount of time that it takes them to dig and peel the root with traditional wooden tools.

In order to determine whether the differences in technological efficiency are likely to have had important effects on overall time allocation or women's food production among the Machiguenga, we need to estimate what level of work effort would have been necessary with wooden tools if daily per capita consumption of manioc calories was the same in the past as it is today. We also need to pay special attention to those subsets of women that are currently working the highest number of hours daily, in order to determine if they could have produced as much food in the past with traditional tools. Because evidence from preindustrial societies indicates that the number of weaned dependents a woman has is an important determinant of how much time she allocates to subsistence work (Hurtado et al. 1985; Hurtado and Hill n.d.), mean daily time spent digging and processing manioc by Machiguenga women was analyzed as a function of the number of dependent small and grown children a woman has living in her household. Machiguenga women at Tayakome gathered manioc every three days on average (n = 248 days; 75 manioc harvest days). While most women were observed to harvest manioc only once on any given day, women with three dependent offspring occasionally went out twice a day (n = 6 woman days). As expected, mean kilograms of manioc acquired per day by women was positively correlated with the number of offspring that live with those women (p = .013; R^2 = .51; Figure 1).

Machiguenga women's time allocation to subsistence activities each day is the sum of many different activities, only some of which are affected by the technological change described here. Each day some time is spent harvesting, processing, and cooking garden foods. Harvesting can be divided into time spent walking to and from the fields and time spent digging roots. Time spent walking is not affected by technology and is about 17 mins./woman day in our sample (n = 75 manioc harvesting days). Time spent digging manioc roots is considered below. Finally, time spent processing consists of the time necessary to peel the roots and the time spent cooking them (bringing water and firewood, tending the fire). Cooking time, not affected by technology, was estimated at 31 mins./woman day in our sample (n = 42 woman days). Peeling, which is affected by technology, is discussed below.

For women with different numbers of dependents, the number of minutes necessary to dig and peel the manioc they harvest with modern and traditional technology can be calculated directly by dividing the weights of manioc acquired per day (Table 2) by the efficiency rates for harvesting and peeling (Table 1). Total work effort with modern and traditional technology is then calculated by adding in the work effort categories not affected by technological change, mainly, time spent cooking and walking to and from manioc fields (Table 3). The results show that traditional technology only increases total work effort for Machiguenga women between 10 and 42 percent. Even for the most work-laden women (5 dependent category), the work effort using traditional wooden tools would only total 95 minutes per day if they continued to harvest and process the 15 kilograms of manioc they currently acquire every three days (about 16,200 calories). This is enough manioc to feed a woman, her five dependents, and her husband at a rate of 2,314 cals./person day.

These analyses indicate that the relative differences in efficiency across modern and traditional technologies do not strongly affect overall female work effort because of the extremely high food return rates that Machiguenga women can obtain per hour of work. The hourly return rate for digging and peeling

TABLE 1
Experimental Events

DIGGING
(kilograms/hour)

Case No.	Machete (a)	Broken Bow (b)	(a) – (b)
1	119	39	60
2	216	114	102
3	240	150	90
4	129	51	78
5	137	60	77
Mean	168	83	85
SD	56	47	11

Student's t-test, p (one-tailed) = .0015

PROCESSING
(kilograms/hour)

Case No.	Machete (a)	Wooden Spoon (b)	(a) – (b)
1	100	16	84
2	60	16	44
3	61	48	13
4	58	24	34
5	72	32	40
6	36	13	23
7	72	26	46
Mean	66	25	41
SD	19	12	23

Student's t-test, p (one-tailed) = .00003

TABLE 2
Number of Kilograms of Sweet Manioc Harvested by Women as a Function of Number of Dependents

Number of Dependents	Number of Kilograms Produced per Day	Sample Size (n)
0	2.8	5
1–2	6.5	5
3–4	8.0	4
5	15.0	1

TABLE 3
Daily Minutes Spent in Manioc Harvesting and Processing by Women as a Function of Technology and Number of Dependents

	Activities Affected by Technology (minutes)		Activities Not Affected by Technology (minutes)	
Number of Dependents	Digging and Peeling with Metal Tools	Digging and Peeling with Wooden Tools	Walking to and from Fields Plus Cooking (constant)[a]	Percent Increase in Work Effort
0	4	9	48	10
1–2	8	20	48	21
3–4	10	25	48	26
5	19	47	48	42

a. This number is the sum of the mean number of minutes spent cooking (31 mins./woman day) plus the mean number of minutes spent walking (17 mins./woman day) by the average Machiguenga woman.

manioc with metal tools is about 51,840 cals./hr., or enough food to feed twenty-five adults for one day.[2] This efficiency rate allows Machiguenga women to spend relatively few minutes per day digging and peeling manioc and, in fact, gives them considerable leniency in the time adjustments they may be prompted to make in response to the introduction or loss of modern tools.

DISCUSSION

The most important implication of these findings is that the adoption of metal tools by indigenous women is only likely to lead to important changes in diet and time allocation when the return rates in root digging and processing are significantly lower than the ones found among Machiguenga women. A bar graph of the number of hours spent just digging roots as a function of hourly return rates (Figure 2) illustrates this relationship. The two bars furthest left on the graph (x = 15 kgs/hr., y1 = 0.1 hrs./day, y2 = 0.2 hrs./day) are taken from the analyses presented above when the number of consumers equals seven (five dependents plus husband and self) and food consumption is 2,314 tuber cals./person day. All other bars represent calculations that assume that when root digging rates decrease two-fold, women will work twice as long. This hypothetical graph shows that while the percent increase in work effort is constant across digging rates, the absolute number of minutes greatly increases as these rates decrease.

While it may be unlikely that tuber acquisition rates in societies dependent upon *domesticated* species would ever reach a level lower than 20 kgs/hr., the root digging rates that have been measured to date in places where *wild roots* constitute important food staples (mainly among hunter-gatherers) range from 0.52 to 12.4 kgs/hr. (the Batak, Batek Negrito, Hadza, and Hiwi foragers; Eder 1978; Endicott 1979; Hawkes, O'Connell, and Blurton Jones 1989; Hurtado and Hill n.d.). Time spent digging roots with metal and wooden tools as a function of the return rates measured to date among foragers are included on the bar graph. If root digging rates are this low, daily per capita tuber consumption is approximately 2,000 calories, and the number of consumers equals seven, our hypothetical graph suggests that women who gather roots regularly would have to spend from 2.7 to the impossible number of 64 hours per day digging tubers with traditional tools. Metal tools reduce their work load by half. The effect of metal tools on time spent acquiring roots is most significant when digging return rates drop below 10.5 kg/hr. spent digging because time adjustments of two hours and more are necessary in order to maintain a daily per capita tuber consumption and family size equivalent to those observed among the Machiguenga.

In summary, experimental measurements of sweet manioc harvesting and processing among the Machiguenga of the Manú River Basin show that the effect of adopting metal tools on women's behavior has been minor because food return rates for harvesting sweet manioc are extremely high in this hor-

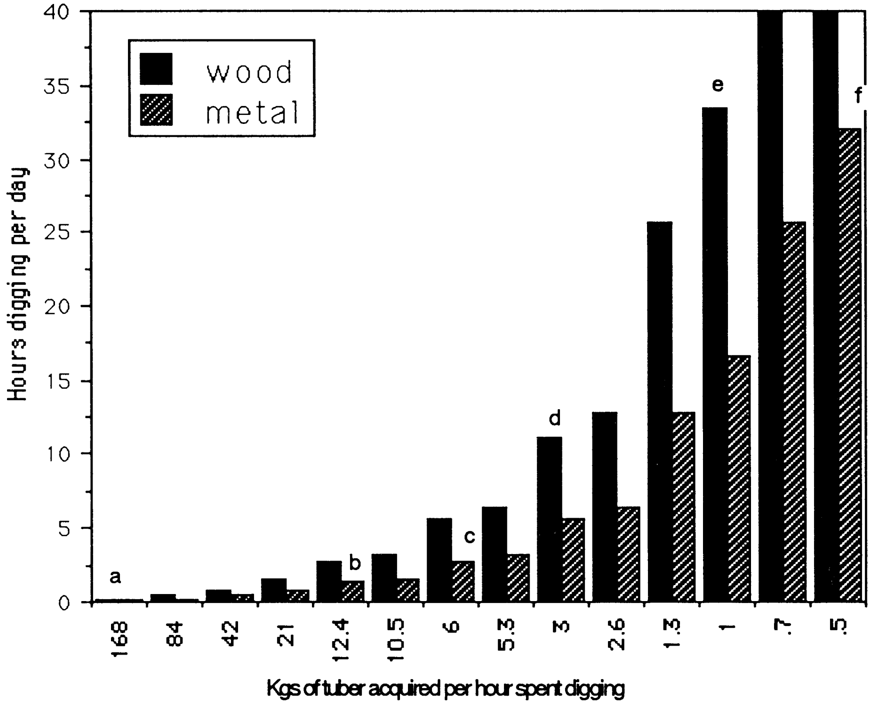

Figure 2. Hours Spent per Day Digging Tubers by Women as a Function of Number of Kilograms Acquired per Hour Spent Digging

Number of dependents and daily per capita tuber consumption are assumed to equal 7 individuals and 2,314 calories, respectively.

Key:

Letter	Measured Return Rates	Technology	Group and Sources
a	168.0	metal	Machiguenga (see text)
b	12.4	metal	Hiwi (Hill 1988; Hurtado and Hill n.d.)
c	6.0	metal	Hiwi (Hurtado and Hill n.d.)
d	3.0	wooden	Hadza (Vincent 1985)
e	1.0	wooden	Hadza and Batek (Hawkes, O'Connell, and Blurton Jones 1989; Vincent 1985; Endicott 1979)
f	0.5	?	Batak (Eder 1978)

ticultural society. However, if we extrapolate the findings to other local ecologies where return rates from harvesting roots are considerably lower, we find that women's daily work effort, dietary contribution, and, consequently, the sexual division of labor could be significantly affected by the introduction of metal tools. The experimental procedure allowed us to determine that changes in an ecological variable (i.e., female technology) do not necessarily lead to the emergence of new behavioral patterns. At the same time, it permitted us to specify the conditions under which the introduced factor might have important behavioral consequences. The results should therefore make us cautious about assuming that adoption of modern technology severely alters native lifestyles in ways that cannot be predicted or understood.

NOTES

1. We are very grateful to the women of Tayakome for participating in our research and to our Machiguenga female informants. We are also thankful to Hillard Kaplan for his collaboration in every phase of the Manú project and to Monique Borgerhoff-Mulder for comments on the manuscript. Fieldwork among the Machiguenga was funded by the National Science Foundation.

2. The formula used to calculate this return rate is:

$$\frac{1\text{ kg }(0.8\text{ edible portion x }1350\text{ cals./kg})}{(1\text{ kg}\div 168\text{ kg/hr. digging}) + (1\text{ kg}\div 66\text{ kg/hr. peeling})}$$

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