IMPROVING THE HEALTH, SAFETY, AND PRODUCTIVITY OF WOMEN VEGETABLE FARMERS IN THE GAMBIA

by

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To my parents, Dale and Susan Vanderwal, my family, and all my friends around the world.
Thanks for all your prayers, support, and encouragement throughout the years!

Soli Deo Gloria

Latin religious texts

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ABSTRACT

Vegetable farming is an important, yet laborious occupation worldwide, often engaging vulnerable populations such as migrant workers in the USA and women in developing countries such as The Gambia (West Africa). Few interventions have been developed, or rigorously tested, to reduce the drudgery, pain and injury-risk inherent in this work. This mixed-methods research evaluated the effectiveness and acceptability of locally-available interventions, selected in a participatory manner, to improve the safety and work efficiency of three tasks of women vegetable farmers in The Gambia. Evaluations of interventions for two tasks are presented in this manuscript.

Qualitative methods, including focus groups, subject observation, and individual interviews were utilized to select interventions evaluated in this research. Subjects (n=48) then engaged in timed trials, alternating between using traditional and intervention methods to accomplish a specified task. Heart rates were measured and subjects reported their discomfort and safety after each trial. Two months later, individual interviews were conducted on subject perception of interventions. Focus group discussions were held one and three months after initial trials.

This research demonstrated that interventions selected in a participatory manner can accomplish the following:

a) increase worker productivity (long-handled hoe for land preparation);

b) decrease work-related musculoskeletal discomfort and injury risk indicators (long-handled hoe; pump for water lifting); and

c) present indicators of long-term acceptance and increased use among subjects after initial trials [land preparation hoe interventions (94% of subjects preferred after

two months), particularly the short-handled hoe; water pump (77% preferred after two months)].

The qualitative findings identified barriers and enabling factors to long-term sustainability of the interventions.

This research demonstrated the importance of comprehensively evaluating interventions for productivity, comfort, safety, and worker acceptability as results may differ in each. For example, in both tasks evaluated, the method which resulted in higher productivity was less preferred by most subjects.

Information from this body of research can help identify and improve current interventions which could be implemented in other settings, help develop related future interventions, and be applied as a methodological model in future studies to improve hand-labor intensive agriculture worldwide.

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CHAPTER I

INTRODUCTION

Agricultural labor

Agriculture is an essential industry throughout the world, providing the food and fiber needed for life and often serving as the major source of export earnings for developing countries. While a small proportion of the population in developed countries (less than 3% in the USA) is involved in agriculture, a majority (approximately 60%) of workers in developing countries are engaged in agriculture (ILO, 2000). While agriculture is critically important, it has also long been cited as being one of the three most hazardous industries, in both developed and developing countries (ILO, 2000). Kuye and others (2006b) demonstrated a high rate of agriculture illnesses and injuries in the Gambia, including sprains and strains, and also demonstrated that the hand hoe is the principle source of injury on the farm. However, few efforts are being made to improve the situation in countries such as the Gambia because farmers are often seen as uneducated and are normally self-employed (O'Neill, 2000).

Women in agriculture

The number of men in the agricultural workforce in developing countries continues to decrease as they move toward industrial jobs, large cities, or may be involved in war or other activities (Hurst et al., 2005). Further, women in countries such as the Gambia are already primarily responsible for tasks such as vegetable production, but are generally illiterate and have low control over their working conditions. Most farm tools are designed for men, thus are typically too large and heavy for women to safely and comfortably handle (FAO/IFAD, 1998). In addition, in countries such as the Gambia, men typically purchase such tools for the women in their household and also determine the acceptable working posture and conditions of these women (FAO/IFAD, 1998).

Musculoskeletal disorders/discomfort (MSDs) and injuries

In both developed and developing countries, vegetable farmers are exposed to several physical risk factors for MSDs. These risk factors include: a) heavy lifting (particularly in harvesting of vegetables and carrying on the head), b) awkward sustained postures (stooped labor in land preparation, planting, weeding, harvesting), c) highly repetitive tasks (land preparation and weeding), and b) frequent use of force (using short handled hoes to turn compacted soil for planting) (Janowitz et al., 2000). It has been shown that similar heavy physical tasks in other industries are associated with high risk for MSDs, including lower back disorders (Fathallah et al., 2008).

In the USA, sprains and strains are the most common occupational injuries in the production of vegetables (NIOSH, 2001). These injuries may also be common in developing countries, as vegetable production is an inherently labor- intensive activity. Women vegetable farmers in the Gambia have similar characteristics to migrant vegetable farm workers in the USA, whose most commonly reported occupational illnesses or injury is work-related MSDs (Villarejo & Baron, 1999).

Interventions in labor-intensive agriculture

In addition to the preventable MSDs and injuries that occur in labor-intensive agriculture, such agriculture could become much more productive by using some simple interventions. However, as stated by Kaul (1993), most farm labor managers and planners do not realize that ergonomic interventions can also increase labor efficiency. Improving efficiency would increase the availability of nutritious vegetables for consumption by the farm family, as well as provide a source of essential income for the family by selling produce in the marketplace.

Work efficiency

Little quantitative information is currently available on the work productivity and energy expenditure of farmers, particularly women farmers in developing countries. The rate and physiology of work in this group are impacted by a number of factors. First, vegetables are a perishable commodity with a short growing season, which prompts farmers to work at a rapid pace to preserve this fragile product in order to get the best price in the marketplace (Faucett et al., 2007). Further, when women farmers are working together with a group, as normally occurs, their camaraderie may prompt them to work harder, or they may stop to take more breaks with each other. They also work under the hot sun for long hours and are generally self-employed, so they may self-adjust their work pace to accommodate their needs.

Overall worker productivity among migrant farm workers in the USA has been shown to increase by more frequent, brief periods of rest (Faucett et al., 2007). A small intervention study in Nigeria (n=4) showed that the use of a hoe with a longer handle reduced the rate of human energy expended from 7.7 kJ/ minute to 4.7 kJ/ minute (Nwuba & Kaul, 1986). However, little information is currently available on whether women will work harder (and thus have an elevated heart rate) when using a less productive method, so that they feel that they can accomplish the same amount of work in a given time, or whether women will simply work at the same heart rate and accomplish a greater quantity and quality of work in the same amount of time. Accordingly, this research provides important information which can improve the productivity of farmers, while also reducing the physiological stress on their body.

Selection and implementation of interventions

Although labor-intensive vegetable production has long been known to lead to MSDs and injuries, few practical and useful improvements have occurred to the tools, implements, or work practices used in vegetable production (Faucett et al., 2007), particularly in developing countries (Rogan & O'Neill, 1993). Although engineering improvements are considered the most desirable way to improve all occupational health and safety outcomes, such interventions must be task- specific, feasible, and culturally-appropriate to be effective in settings such as women's vegetable farming in the Gambia (FAO/IFAD, 1998; Faucett et al., 2007). However, it is challenging to implement interventions that will perform under field conditions and will be accepted by the women themselves, as well as the entire community. Despite these challenges, a stakeholders' workshop organized in the Gambia by Kuye and others (2006b) did recommend that appropriate interventions should be implemented and that the ergonomic and safety conditions of hand tools among farmers in the Gambia should be further researched. Many other groups have also emphasized the need for such intervention studies to be conducted (FAO/IFAD, 1998; Rogan & O'Neill, 1993)

The careful selection of interventions to be implemented is essential, as other researchers have shown the importance of factors such as innovation complexity and compatibility with current worker practices and values to be very important in the adaptation of the innovations by agricultural workers (Earle-Richardson et al, 2005). Involving the workers in the intervention selection and development process is very important to increase long-term acceptability and use of the intervention, and has also resulted in more healthful, productive, and comfortable products (Rosecrance & Cook, 2000; Vink & van Eijk, 2007). Interventions can be very low-cost and still be effective, as demonstrated by the WIND (Workplace Innovation in Neighborhood Development) methodology promoted by the International Labor Organization (ILO, 2005). This approach utilizes existing local networks for the identification and dissemination of low-cost, feasible interventions that local farmers have already implemented, so that others can also benefit.

Reduction of MSDs and injuries in agriculture

Although some interventions have been tested in the USA, the Netherlands, Sweden, India, Nigeria, and some other countries, it is not clear how much progress has been made in reducing MSDs and injuries in agriculture. A systematic review of farm safety interventions found little evidence of successful preventive programs (Deroo & Rautiainen, 2000). Various studies conducted in developing countries have shown that improved tools performed more effectively and allowed the worker to be more efficient in the completion of a given task (Rogan & O'Neill, 1993). However, further research is needed to test various interventions and quantify the resultant increased productivity and decreased MSDs and injuries (Rogan & O'Neill, 1993; FAO/IFAD, 1998).

Many of the previous studies on risk factors for MSDs and injuries have been cross-sectional in nature, extremely limited in the number of participants, and/or have relied on subjects to recall past events, sometimes longer than one year. Accordingly, this study provides useful information on possible interventions to be implemented to improve the health, safety and productivity of women vegetable farmers, as well as a methodological model for selecting and evaluating such interventions.

Significance of this research

Vegetable farming is an important, yet labor-intensive occupation worldwide. In both developed and developing countries, repetitive manual labor and an absence of safety precautions are common (Fathallah, 2008). In developed countries, some tasks such as land preparation, watering, and transport are somewhat mechanized, but in developing countries, these tasks are still largely done with the most primitive methods.

Any improvements that have been made in this area in developed countries may be very difficult for farmers in developing countries to access and utilize. Further, in most developing countries, women would have little access to any improvements that may be made (FAO/IFAD, 1998; Rogan & O'Neill, 1993). The most successful interventions that have been tested in the USA in this sector tend to be those developed and selected in a participatory manner (Meyers et al., 1997; Baron et al., 2001; Earle-Richardson et al., 2005).

In developing countries such as The Gambia (West Africa), vegetable production is a very important economic activity, which is typically carried out by women in small-scale community gardens (Carney, 1998). Some development organizations are working to assist such farmers to improve their vegetable production and may implement various well-intentioned interventions. However, their long-term acceptability and effects on worker health and safety have rarely been rigorously studied. Even fewer agricultural projects in developing countries have involved the beneficiaries (particularly when they are women) of an intervention in its selection and development, although this is essential for ensuring the acceptability and long-term use of the intervention (FAO/IFAD, 1998; Kaul, 1993; Rogan & O'Neill, 1993).

Hypothesis and aims of this research

Accordingly, the specific hypothesis driving the research presented in this dissertation was that compared to traditional work methods, interventions chosen in a participatory manner will:

a. increase worker productivity;
b. decrease work-related musculoskeletal discomfort and injury risk indicators; and
c. gain long-term acceptance and increased use among the subjects after the initial trials.

The research is divided into three chapters with the following specific aims:

1. Establish an effective community participatory process with women vegetable farmers in The Gambia (study subjects) to select interventions to be tested in future studies.

2. Evaluate the effectiveness of interventions (long- and short-handled hoes) for land preparation among the study subjects, as well as to identify barriers and enabling factors essential for long-term sustainability of the interventions.
3. Evaluate the effectiveness of a hand water pump for water lifting among the study subjects, as well as to identify barriers and enabling factors essential for long-term sustainability of the intervention.

This research was designed to use mixed methods (Creswell et al., 2003). We used qualitative data collection, including focus group discussions, subject observations, and targeted interviews to select the interventions. Quantitative methods were then utilized to describe worker productivity, discomfort and injury risk indicators, and some indicators of long-term worker acceptance of the land preparation and water lifting interventions, through timed trials and individual interviews. To compliment these data, qualitative individual interviews, focus groups, and observations were also conducted to identify barriers and enabling factors that are essential for long-term sustainability of the interventions.

The long term goal of this research is to improve occupational health and safety, as well as work productivity, in hand-labor intensive agriculture in Africa, although the information could also be useful in immigrant and migrant worker populations in the USA.

CHAPTER 2

ESTABLISHING A COMMUNITY PARTICIPATORY PROCESS TO SELECT INTERVENTIONS TO IMPROVE HEALTH, SAFETY, AND WORK PRODUCTIVITY OF WOMEN VEGETABLE FARMERS IN THE GAMBIA

Summary

Vegetable farming is an important, yet laborious occupation worldwide, often engaging vulnerable populations such as migrant workers in the USA and women in developing countries such as The Gambia. The purpose of this study was to establish an effective community participatory process to select interventions for testing in future studies, which can help to improve the health, safety, and work productivity of women vegetable farmers in The Gambia. This qualitative study describes the main tasks undertaken by the subjects in the garden, the tools currently used, the challenges encountered in these tasks, and the interventions selected to be evaluated in future studies. The interventions selected include an improved short-handled hoe and a long-handled hoe for land preparation, a hand-cranked pump for water lifting, as well as a plastic tray for transporting vegetables. The paper identifies some of the key factors contributing to the successful implementation of the community participatory process in this study, which may be useful in utilizing this type of research in other labor-intensive agriculture settings throughout the world.

Introduction

The demand for fresh vegetables year-round continues to grow worldwide, leading to a corresponding increase in vegetable production (FAO, 2008). However, vegetable farming is also very demanding on the workers as it involves long hours of hazardous repetitive manual labor, awkward working postures, and often a lack of safety precautions (Janowitz et al., 2000; Fathallah et al., 2008). The working conditions in vegetable fields around the world are similar in many aspects, and minority workers provide most of the labor: migrant and new immigrant workers in the USA, and small-scale women farmers in developing countries such as The Gambia (West Africa). Vegetable production is a very important activity for women in The Gambia, providing healthy produce for their families and a potential source of income through its sale (Carney, 1998).

Vegetable production entails many well-established risk factors for musculoskeletal disorders/discomfort (MSDs) and injuries, and has been shown to result in such outcomes in the USA (Villarejo & Baron, 1999; NIOSH, 2001). However, a relatively small number of improvements have occurred to the tools, implements, or work practices used in labor-intensive vegetable production (Faucett, 2007). This is particularly true in developing countries, where women would have little access to any improvements that may be made (FAO/IFAD, 1998; Rogan & O'Neill, 1993). The most successful interventions that have been tested in the USA in this sector tend to be those developed and selected in a participatory manner (Faucett et al., 2007; Baron et al., 2001; Earle-Richardson et al., 2005).

Numerous researchers in labor-intensive agriculture in the USA (Faucett et al., 2007; Baron et al., 2001; Earle-Richardson et al., 2005; Meyers et al., 1997) have utilized this participatory approach to involve workers and their managers in the design, evaluation, and eventual implementation of interventions intended to reduce task-related injuries and work-related MSDs. Such an approach has been shown to be the most effective at improving work-related health outcomes, and also helps to ensure that the ideas are relevant to the worker and will be utilized in the future (Baron et al., 2001). Most studies utilizing a participatory approach use qualitative data-collection methods, which provide information on the perceptions of individuals, and help to inform the development of interventions (Creswell, 2009).

Unfortunately, this approach of involving the beneficiaries (particularly when they are women) of an intervention in its development and evaluation is rarely utilized in agriculture in developing countries (FAO/IFAD, 1998; Kaul, 1993; Rogan & O'Neill, 1993). Accordingly, the specific hypothesis driving the research introduced in this paper was that compared to traditional work methods, interventions chosen in a participatory manner will:

a. increase worker productivity;
b. decrease work-related musculoskeletal discomfort and injury risk indicators; and
c. gain long-term acceptance and increased use among the participants after the initial trials.

The specific aim of the study described in this paper was to establish an effective community participatory process to select interventions for testing in future studies. As part of this aim, this paper also describes the research setting, the main tasks undertaken by the subjects in the garden, and the interventions selected to be evaluated in the larger research program.

This aim will be achieved through use of qualitative data collection, including focus group discussions, subject observations, and targeted interviews.

Methods

Research setting

Due to the interest and experience of the principal investigator (PI) in working in Africa and the long-standing collaboration between the University of Iowa and the Gambia College in agriculture health and safety, this research project was conducted in The Gambia (West Africa). The Gambia is a small country (11,000 km^2), lying between 13 and 14 degrees north latitude. It consists of a narrow strip of land lying inside of the country of Senegal, following the Gambia River some 400 km from the Atlantic Ocean in the west (see map in Figure 2.1). In 2008, The Gambia was positioned at 160 out of 179 countries worldwide in the United Nations Development Program (UNDP)'s Human Development Index. Poverty is pervasive with 50% of the population living on less than $1 USD per day (UNDP, 2008).

Figure 2.1. Map of The Gambia within West Africa

In June and July 2007, the PI visited The Gambia to make plans for the research project and to network with local agencies and individuals to assist in the implementation of the research. The PI returned to The Gambia in October 2008 to initiate this research project, working closely with officials and students from the Gambia College in its preparation and implementation, particularly Dr. Rex Kuye, Vice Principal of the Gambia College, who conducted similar research with farmers in The Gambia (Kuye et al., 2006b). A relationship was established with the Trust Agency for Rural Development (TARUD), a local non-governmental organization (NGO), who agreed to allow the research project to be conducted in the women's vegetable garden they established and oversee.

This garden was located 1.2 km east of the village of Gunjur, in the Kombo South district of the Western Region of The Gambia. The climate in the region of the garden is characterized by a long dry season (late October to May) and a short rainy season (June-early October), with rainfall ranging from 900 mm to 1,100 mm annually. The total size of the garden in the research project is 4.2 hectares, with generally deep, well-drained soils. The western part of the garden consists of gentle rolling slopes with sandy loam overlying sandy clay loam soil within 125 cm, which is slightly acidic (pH 5.5-6.5). The eastern part of the garden consists of deep (>125 cm), well drained, moderately permeable sandy loam soil of medium acidity (pH 5.5) (Ceesay, 2009).

Subjects

A total of 212 women work in the garden where the research project occurred, each in her own plot. These women had previously been divided into twelve workgroups, arranged by the geographical location of their plot in the garden. Each group had a leader, generally chosen for their farming ability, their leadership and communication skills, and their years of garden experience (Ceesay, 2008). The leaders also work in their own plots in the garden, in the same manner as the other subjects, and do not receive any compensation for their leadership role. The women also selected a president, vice-president, and "organizer" of the entire garden, which were considered the most important roles in the garden. To maintain the garden leadership's support of the project, it was important that each workgroup leader was a subject in the research project. Three other women from each working group were also randomly selected to take part in the research project.

The PI and local project assistants met with these 48 subjects to introduce the research project, explain the subject eligibility requirements (aged 18 years or over and currently actively engaged in vegetable farming) and administer informed consent, as approved by the Government of The Gambia Human Ethics Committee (SCC/EC #1123) and the University of Iowa Institutional Review Board (IRB ID# 200808704). All of the selected women agreed to participate in the research project. All subjects were provided with a small monetary incentive for their participation, which was not made known to the participants until the end of the study when the compensation was distributed.

Project assistants

The Gambian employee of the local NGO already working as an advisor to the women in the garden served as the main interpreter and liaison between the research team and the subjects for the project. Selected students from an Occupational Health course, taught by the PI, at the School of Public Health at the Gambia College were trained to serve as project assistants, at the suggestion of Dr. Kuye, and the approval of the leadership of the garden. The assistants were trained extensively on research principles in occupational health and were fluent in the local language of Mandinka.

Note also that although the PI of the study could only speak and understand basic Mandinka, a third party (not part of the garden leadership structure or directly assisting with the research) bilingual Gambian accompanied the PI during most of her time in the garden. This person could explain the content of the various discussions and interviews and could check for the interpretation of the questions. This person was typically either a local public health officer or a bilingual driver.

Subject observations

Subjects were observed, primarily over a four-week time period during their routine work in the garden, to note the tasks normally undertaken, the tools used, and to make general observations of inefficiencies, discomfort and particularly injury-prone tasks. The research team members used an open-ended form to document observed activities and behaviors of the subjects in the garden.

Individual interviews

Throughout this study, the research team conducted informal, qualitative individual interviews with the 12 workgroup leaders (considered key informants) in the garden, as well as with one additional randomly selected subject from each of the 12 workgroups (see Table 2.1). All the women that were approached to request interviews accepted to conduct the interviews. Additional subjects were randomly selected for individual interviews, in addition to the workgroup leaders, to reduce the possibility of receiving biased responses from only the workgroup leaders and to also gain perspective from younger subjects with less garden experience. These interviewees were asked for in-depth information regarding a) the tasks undertaken in the garden; b) the pains, injuries, and inefficiencies in these tasks; c) the tools used and their rationale for the use of those tools; d) suggestions and feedback they had for interventions to improve the various tasks in the garden; and e) their feedback on the interventions proposed, discussed, and selected during the focus group discussions. All information was recorded on open-ended forms.

Table 2.1. Interview and focus group participants

Characteristic	Key informant interviewees/ Focus group participants (N= 12 subjects)		Randomly-selected subject interviewees (N= 12 subjects)	
	Mean	**Range**	**Mean**	**Range**
Height (m)	1.55	1.50-1.64	1.62	1.53-1.70
Weight (kg)	56.1	45-64	58.5	45-70
10-year age range	50-59 years	30-39 years to 80-89 years	40- 49 years	18-29 years to 80-89 years
Years garden experience (category)	10-20 years	6-10 years to >20 years	6-10 years	1-5 years to >20 years

Focus group discussions

We utilized the existing leadership structure of the garden and respected the cultural norms of the subjects in conducting the participatory focus groups held during this study. Although focus groups typically include 6-8 people (Morgan, 1997), discussions with the Gambian research assistants and the garden leadership indicated that it was culturally important to have all 12 of the garden workgroup leaders take part in each of the focus group discussions (see Table 2.1). It would be considered offensive and inappropriate to have discussions regarding the garden tasks, and particularly about the selection of interventions, without all the garden workgroups represented. Subjects would also consider it to be culturally inappropriate for the other subjects to take part in a focus group without any of garden leaders involved. Further, the 12 workgroup leaders were generally the best farmers, leaders, and communicators in the garden (Ceesay, 2008), so they can be considered key informants from whom maximum information could be obtained. All subjects were welcome to attend and listen to the focus group discussions, but only the 12 leaders contributed, in accordance with cultural norms. Many of the other subjects in the research project did attend at least a portion of the focus group discussions, but sat quietly behind those actively involved in the focus groups.

All focus group discussions in this study were conducted at the vegetable garden in Mandinka, the local language, for approximately 1-1.5 hours. The discussions were digitally recorded (with the permission of the group) and were simultaneously interpreted into English by a local project assistant. Hand-written notes of this interpretation were taken and typed by the PI. The typed notes (in English) were checked for accuracy by the focus group facilitator and compared to the discussion tapes (in the local language), as necessary, to verify the content of the discussion.

First focus group discussion

In the first focus group, the participants were asked to discuss the following: a) the various tasks they undertake in vegetable gardening; b) the amount of time generally spent on those tasks and the time of year the tasks are undertaken; c) the tools used in each of those tasks, d) pain and injuries incurred during those tasks, and e) practical suggestions they had for low-cost tools/interventions to improve the safety and efficiency of their work. An agricultural technology specialist with the Gambian National Agriculture Research Institute (NARI) also participated in the first focus group to provide insight into possible improvements to the methods currently used, as well as input on the feasibility of locally re-producing interventions.

The project team then provided models of locally-available/reproducible potential interventions for the three tasks determined through the subject observations and individual interviews to be the most time consuming/painful/injury-prone and most amenable to low-cost and culturally-appropriate interventions. Those tasks were land preparation, water lifting, and vegetable transport. These models included 14 long- and short-handled hoes (some shipped from the USA and some purchased locally), information on water lifting pumps, and a flat plastic crate with handles for transporting vegetables. The models were left with the subjects for one week for them to test. Subjects were also encouraged to generate ideas of other low-cost and feasible methods, or modifications to existing methods, to improve the various tasks, which would be discussed in the second focus group.

Second focus group discussion

In the second focus group, the subjects provided feedback on each of the model interventions provided the previous week, as well as suggestions for their improvement. From the ideas proposed by the subjects and the models provided by the research team, the group discussed and agreed upon the interventions to be selected for the three tasks.

Qualitative data analysis

All the information gathered through the various qualitative data collection methods (focus groups, observation, and individual interviews) was immediately analyzed to identify patterns and common themes. A purposeful, deductive approach was used in this research, where we used the information gathered to make specific conclusions regarding the tasks for which interventions should be developed, and as to which interventions should be selected for future research that would be accepted by the participants in the process. The PI worked with the local project team and the focus group facilitator to understand the focus group data both during and immediately after the discussions. Coding of interviews and subject observations were discussed with the local project assistants immediately after completion of the interviews and observations. All opinions expressed by subjects were included in the analysis, with particular attention given to the number of subjects reporting a particular point.

Results

Similar themes emerged from the various qualitative information-gathering methods employed, indicating that we had reached a point of data saturation. The following themes are those that emerged regarding the main tasks in the vegetable garden and the interventions selected for future evaluation. Note that all quotations from subjects are translated into English from the local language of Mandinka.

Vegetable garden tasks and traditional methods used

The main tasks undertaken in the vegetable garden in this study were identified as follows: a) land preparation; b) planting; c) weeding; d) watering; e) harvesting; and f) transporting. For each of these tasks, the amount of time generally spent, the tools commonly used, and the pain and injuries often incurred during those tasks are described below.

Land preparation

Although land preparation is only required for about two weeks per growing season, the first focus group discussion estimated that it requires 3-4 hours of heavy labor per day during the period of time when it is required, typically in November-December (for dry season production) and in May-June (for rainy season production). Subjects were observed to use a locally-made, light, short-handled hoe with a dull metal cutting surface to prepare their land for planting. It was considered by the focus group discussions to be the most injury-prone task in the garden as subjects swing their hoes forcefully toward the ground to till the soil, with the hoe often hitting very near to their feet. The individual interviews and focus groups agreed that the long hours of forceful, stooped labor also cause the task to be very painful. Therefore, focus group participants agreed that interventions should be selected for this task.

Planting

In this garden, the planting was observed to generally require approximately 3 hours of work per day for one week near the beginning of every growing season. Upon observation, the method of planting/transplanting varies according to the vegetable species, which in turn determines the tools used. Typically, the subjects plant seeds/young plants with bare hands and prepare the seed bed with a short-handled local hoe. The focus group discussions and individual interviews indicated that, relative to other garden tasks, planting vegetables is generally less painful and injury-prone. We observed that planting does require stoop labor and repetitive motions, but because of the fewer hours required due to the small garden plot sizes for each woman, there is less time to develop discomfort, which was corroborated by the interviews and focus group discussions. Accordingly, this task was not considered a priority for selection of interventions.

Weeding

Weeding vegetables is relatively time-consuming, with the results of the first focus group and individual interviews estimating that it require approximately 5-6 hours of labor per day for a total of at least 40 days throughout each growing season, which typically lasts from November-April for dry season production and May-October for rainy season production. The tools the subjects use for weeding were observed to typically be similar to those used for land preparation, although subjects also use very small (short-handled) bent metal rods for weeding in narrow areas. The first focus group asserted that weeding also requires long hours of repetitive, stooped labor, which causes it to be quite painful, and similar to land preparation, is also prone to injury. However, upon subject observation, it was determined that accurately evaluating the differences between weeding interventions in future studies would be difficult, as the conditions of weeding vary greatly, depending on the species and density of plants, weed type and density, level of weeds removed, soil moisture level, etc. Further, the interventions for land preparation would be similar to interventions for weeding, thus interventions were only selected for land preparation.

Watering

Watering was stated by the interviews and the first focus group discussion to be the most time-consuming task in the garden, requiring an estimated five hours per day during every day of the dry growing season (November-May), or 60-70% of their total time in the garden. The research team observed that women traditionally drop a bucket (normally a 5-7 liter bucket) tied to a rope into one of the 22 concrete-lined wells in the garden to lift water for their crops, which is poured into larger buckets (typically a 15-liter bucket) and carried to their vegetables, one or two buckets at a time. One of the group leaders stated in an interview that the depth of the wells in the garden can range from approximately 3 meters at the end of the rainy season to approximately 13 meters at the beginning of the next rainy season. The first focus group estimated that they would lift an estimated 400 liters per day, which would require lifting 80 buckets (~5 liters/5 kg each) of water from the well per day. According to the interviews and focus group discussions, due to the long hours of heavy lifting required, water lifting is extremely painful. In the interviews, subjects expressed concern that they did not feel safe having their children help with water lifting, as they were afraid the child may fall into the open well or drop the end of the rope into the well. Subjects in the first focus group discussion also reported hand pain from the poor quality rope used to lift the buckets. Accordingly, the women in the focus group discussion, confirmed by interviews, agreed that an intervention should be selected for water lifting. Transporting water from the well to their plot is also time-consuming and painful, but the focus group agreed that water lifting interventions were a higher priority.

Harvesting

Relative to the other tasks in this vegetable garden, harvesting was stated by the focus groups to be moderately time-consuming as it is done for approximately 4 hours per day for about 20 days at the end of each growing season (February-May and August-October). Vegetables are typically harvested by hand or by cutting with a small knife, according to subject interviews. The first focus group emphasized that harvesting can be very painful as it involves long hours of stoop labor and awkward postures during harvest season. Because of the relatively small area for each woman in this garden to harvest and unavailability of suitable interventions to suggest for improving the actual harvest process, subjects in the focus groups agreed to test interventions for transporting, rather than harvesting, of vegetables.

Transporting

Depending on the amount of produce and the distance each woman must travel, transporting harvested vegetables can be relatively time consuming, according to the focus group discussion, sometimes requiring 10-12 trips from the garden per day during the peak of harvest season. The PI observed that most women carry their produce in large plastic basins balanced on their head, typically at least 1.2 km from the garden to the main road. The weight carried varies depending on the type of vegetable, but a common load would be 20 kg of tomatoes in one basin, based on the PI's observations. Women in the focus groups and individual interviews were also concerned about the quality of the tomatoes carried at the bottom of a deep basin, and that the handles of the basins often broke while lifting them onto their heads. Due to the extreme weight (~20kg) of the vegetables carried long distances on the head, the focus groups emphasized that transport can be particularly painful, and frustrating if the produce (such as tomatoes) at the bottom of the container spoils or if the container breaks. Accordingly, subjects agreed to select interventions for this task.

Interventions selected for future studies

Through the community participatory process that was established, possible interventions for the following tasks were evaluated, with the most promising selected for evaluation in future studies.

Land preparation

The research team provided 14 model hoes for the subjects to evaluate. It was recognized that some of the hoes were more useful for tasks other than land preparation (such as weeding). However, many of the same characteristics useful in weeding hoes are also useful in land preparation hoes, so will also be reported here. Traditionally, women use short-handled hoes in vegetable farming for land preparation, as well as for weeding. In other parts of the Gambia, women often raise rice in the swampy areas near the Gambia River, and use a longer handled hoe in the preparation of the land used for rice planting. These women would be more accustomed to using longer-handled hoes.

Based on the feedback provided in this study, primarily in the second focus group discussion, subjects considered the characteristics listed in Table 2.2 to be important in selecting a hoe.

The women in the second focus group then selected one short-handled (which was purchased locally) and one long-handled hoe (shipped from the USA) to be tested in future studies (see Figure 2.2). The agricultural engineering unit of the Gambian National Agricultural Research Institute (NARI) was contracted to manufacture copies of the hoes.

Table 2.2. Characteristics important in selecting a hoe

Characteristic	Explanation
Light weight	Very important; yet it must still maintain strength and durability
Strength	Must be able to dig hard, dry soil without risk of breakage; long-lasting
Versatility	Tools with 2-sided heads are beneficial as they can be used for more than one operation (digging and breaking clumps, for example); resource-poor farmers need versatile equipment as they may only be able to afford one tool. It is also easier for subjects to carry only one tool to the garden.
Size of head	A wider soil-cutting surface to work large areas of ground more quickly is beneficial.
Familiarity	For example, a stirrup hoe (for weeding) was demonstrated to the women, which they had never seen before, but they could not understand how it could be used and thought it was too weak to be useful.
Ease of use	Sharp cutting surface on the metal head to more easily enter the soil

Figure 2.2. Model hoes selected through the community participatory process (on the outside of the photo), with the locally-manufactured short and long-handled hoes in the center. Note that the handle of the model long-handled hoe was cut for shipping to the Gambia and rejoined with the silver metal plate.

Water lifting

Subjects proposed a wide range of possible interventions for water lifting. The focus group's first proposal was a bore hole well with a motor-driven pump, so that they could just turn on a faucet to have water. However, the high cost (>8000 USD) of installing such a system was prohibitive. Subjects also discussed the need for improved buckets which are less likely to break when lifting them from the well, in addition to replacing their frayed, abrasive rope with a stronger, wide and flat cord. The research team then provided information on a number of manually-operated water pumps, including a foot-operated treadle pump, and various types of hand-operated pumps. Subjects in the focus groups said that the treadle pump and many of the hand-operated pumps discussed were "*too hard*" to pump. In particular, some subjects had used previous models of a hand-cranked rope and washer water pump, which the subjects said was "*very heavy to turn*" and inefficient. However, after further information was presented on the improvements that had been made to the current version of the pump, focus group subjects, as well as those interviewed, very willingly decided to test the new rope and washer pump (see Figure 2.3). The pump was promoted and sold by an international NGO working in The Gambia, but was manufactured and maintained locally, by Gambians.

Figure 2.3. Subject using the hand water pump selected in the study

Transportation

In the focus group discussions, subjects suggested that large wheelbarrows could be used to improve transportation of their produce. However, in interviews, subjects noted that it would be difficult to move a wheelbarrow through the narrow paths in the garden and that produce such as tomatoes could very easily be crushed at the bottom of a heavy load when going over the rough paths from the garden to their homes or marketplace. The project team showed the subjects some flat, rectangular plastic trays that could be used for transporting vegetables, which were purchased at a gardening supply store in the largest city in The Gambia (approximately 40 km from the garden) for approximately 5 USD each. The subjects in the focus groups had seen similar trays being used by larger-scale vegetable growers in The Gambia, and enthusiastically selected the tray (see Figure 2.4) to be tested in future studies.

Figure 2.4. Women transporting tomatoes with the crate (intervention - right) and a traditional plastic basin (left)

Discussion

Achieving a truly participative and collaborative research process to develop and select effective interventions requires strong partnerships and achievement of credibility with the farm workers and their leadership (Rogers, 2003; Faucett et al., 2007; Fathallah et al., 2008). Great efforts were made by the research team in this regard, which we feel enabled us to gain the honest and active involvement of the participants in the selection of interventions to be further evaluated in future studies.

In this study, one of the key factors in building these partnerships and credibility was the significant relationships developed between the PI and the leadership of the garden. In Gambian culture, family relationships are very strong and welcoming of guests, particularly those that have a connection with one of their family members, is very important (Culp et al., 2005). This study was conducted in the home village of a Gambian visiting scholar at the University of Iowa, who helped connect the PI with his mother who worked in the garden in the study and his uncle who was the director of the NGO overseeing the garden. Because the PI had helped welcome the visiting scholar to Iowa, his family and fellow villagers warmly welcomed the PI to the village and to the garden.

Efforts were made to ensure that all cultural norms were followed in the preparation for and in the conducting of this study. For example, top officials from the Gambia College formally visited the NGO overseeing the garden to request their collaboration with the study prior to the PI's arrival, which was a critical part of following cultural protocols. The PI had previously spent two months in The Gambia, and had lived and worked extensively in other parts of Africa prior to the study, which provided much-needed insight into Gambian culture. However, the PI also tried to ensure that all decisions and actions taken regarding the study were discussed with the Gambian garden advisor and/or Gambia College officials and any other relevant experts, to ensure cultural appropriateness and feasibility.

Use of the existing garden leadership structure, particularly the 12 workgroup leaders, and partnering closely with the existing Gambian garden advisor was also essential to gaining the full and active involvement of the subjects in this participatory process. In this way, the implementation of the study did not threaten, but rather reinforced the existing structure in the garden, which facilitated the full support and participation of the garden leadership, and thus of all other subjects as well. A great deal of information was gained in the interviews with key informants and the subject observations. However, to truly engage all the subjects in a community participatory process, it was important to also conduct the focus groups and to allow all subjects to attend, which should also facilitate all subjects' active involvement in the intervention testing in future studies. The information gained from these focus groups also confirmed that we had reached a point of data saturation, validating the information gained in the interviews and observations. Although the format of the focus group discussions used in this study was different than typical focus groups (Morgan, 1997), we feel that they were successful and importantly, followed cultural norms to ensure active subject participation in future studies.

Care was taken to ensure that all those assisting with the study were seen as non-threatening and familiar. The main Gambian student (a male) assisting with this study worked as a community health nurse in villages similar to the one in the study for eight years prior to returning to the School of Public Health, and was skilled in working with village women. The other student assisting with this study was a female originally from a neighboring village, and was well accepted by the subjects.

Research team members also made an effort to work with the subjects for an extended period of time in every task they undertook in the garden, in order to gain first-hand understanding of all the tasks and to build credibility with the subjects (Faucett et al., 2007). The PI also learned the basic greetings and conversations in the local language, which helped to strengthen relationships with the women. These points also may have helped to reduce the "Hawthorne Effect" as it allowed the subjects to become familiar with the researchers, so they would be less likely to perform differently simply because they were being studied.

Other studies have also shown the benefits of utilizing a community participatory process in developing effective interventions as it help ensure that the products of the research process are more relevant to the needs of the participants (Rivilis et al., 2008; Rosecrance & Cook, 2000; Vink & van Eijk, 2007). This is particularly important when developing interventions to assist women farmers in countries such as The Gambia, as men are typically responsible for making decisions and for making tools, so it is important that women's opinions are also considered (Kaul & Ali, 1992; FAO/IFAD, 1998; Egharevba & Iweze, 2004). Further, it is important for the subjects to present their own ideas for interventions as they know their farming system best and have invaluable local expertise and traditional wisdom that may lead to extremely effective interventions (ILO, 2005; Hellin, 2006).

As indicated in the hypothesis of this overall body of research, one of the key benefits to utilizing a participatory process in the selection of interventions to be tested is that those interventions should gain long-term acceptance and increased use among the participants after the initial trials. Some important factors impacting the use of interventions after the initial trials are that they are a) locally-available and maintainable and b) available at a reasonable cost (FAO/IFAD, 1998). Some possible interventions for these tasks may be feasible in developed countries, but would not be feasible for the subjects to implement or maintain themselves after the completion of this study. However, one intervention -- the flat plastic trays for transporting vegetables -- was adopted from the NIOSH Simple Solutions manual (Baron et al., 2001) developed in the US. Thus, this intervention will be validated in a different setting than previously tested.

The participatory process may have been more effective if the subjects were allowed more time to generate ideas for interventions and to evaluate the model tools provided, or were provided with more information about possible interventions. Additional focus groups could also have been conducted. However, the PI had limited time in The Gambia to conduct the entire body of research, so following a time line for each phase was necessary. As described, numerous steps were taken to build a strong partnership with the subjects, in an attempt to receive honest information (Faucett et al., 2007). However, it is likely that subjects may have responded to some questions with information that they thought the interviewer wanted to hear or with information that they felt would provide them greater future benefit. Interpretation of the discussions between English and the local language were time-consuming and tedious at times, but it was critical that information was interpreted accurately. Also, data from only one garden may limit the generalizability of the results.

These points can all be addressed in future studies. More focus groups could be conducted over longer time periods in this garden, and the work could be expanded to other gardens, particularly as the PI now has greater insight into Gambian culture and language and the implementation of a community participatory process.

Despite the challenges of conducting such research in a developing country, it was beneficial in many ways. The subjects should greatly benefit from the interventions selected in the study, and the many other women vegetable farmers in The Gambia and in Africa may also benefit from use of the interventions selected in the study, or at least from the implementation of a community participatory approach to select interventions. The scientific merit of the research also benefits from the large population of farmers available in most developing countries, high subject participation rates (Kuye et al., 2006b), and the helpful assistants willing to assist with such studies.

Conclusions

In this study, we were able to establish an effective community participatory process to select interventions which will be evaluated in future studies. Information was gained through subject observation, targeted interviews with key informants, and two focus group discussions. The main tasks undertaken by the subjects in the garden, the tools currently used, and the challenges encountered in these tasks were described. Interventions were selected for the tasks of land preparation, water lifting, and transport, which will be evaluated in future studies.

It is recognized that although vegetable gardening is relatively labor-intensive throughout the world, the specific details of the tasks do vary, particularly between developed and developing countries. Therefore, some of the interventions developed -- particularly for water lifting -- may not be applicable in developed countries. However, the development of a community participatory process to select interventions would be very useful in labor-intensive agriculture throughout the world. Many small-scale farmers, particularly in developing countries do use similar traditional methods as described in this study. Accordingly, many farmers, particularly women vegetable farmers, can benefit from the implementation of a community participatory process to discuss a) the tasks they undertake in their work, b) the tasks where interventions are most needed and most feasible, and c) possible interventions that can be tested in further studies.

CHAPTER 3

EVALUATION OF LONG- AND SHORT-HANDLED HAND HOES DEVELOPED IN A PARTICIPATORY MANNER TO IMPROVE WORK PRODUCTIVITY, HEALTH, AND SAFETY AMONG WOMEN VEGETABLE FARMERS IN THE GAMBIA

Summary

Background: Land preparation requires long hours of heavy physical labor for women vegetable farmers in countries such as The Gambia, West Africa. This mixed-methods study evaluated land preparation interventions (long- and short-handled hoes) developed in a participatory manner, and identified indicators of their long-term sustainability.

Methods: Subjects (n=48) engaged in timed trials, alternating between using an intervention tool and their traditional hand hoe to till specified plots of land. Average and maximum heart rates were measured and subjects reported their discomfort and safety after each trial. Two months later, individual interviews were conducted on subject perception of the tools, and focus group discussions were held one and three months after the initial trials.

Results: Compared to using the traditional hoe, subjects tilled plots of land with the new long-handled hoe in 22% less time (p=0.01), while the new short-handled hoe took 20% more time (p=0.05). Compared to the new short hoe, the new long hoe took 35% less time (p<0.01). Compared to the traditional hoe, use of the new long hoe significantly reduced lower back discomfort (OR= 0.19, 95%CI= 0.07-0.50), hip and leg discomfort (OR=0.22, CI= 0.08-0.63), and injury near misses (OR= 0.33, CI= 0.13-0.83). Use of the new long hoe significantly reduced discomfort in all body regions, as well as injury indicators, when compared to the new short hoe. Two months after the initial trials, 94% of subjects reported that they preferred the new hoes. When compared to the new

long hoe, most subjects (75%) preferred the new short hoe and thought it was faster (81%). The qualitative findings indicated that the new tools caused less discomfort and increased productivity, durability, and safety. Short-handled hoes were considered by the subjects to be more versatile and durable than long-handled hoes.

Conclusions: In order to assess their long-term utility, interventions were evaluated for productivity, comfort, safety, and worker acceptability. While the new long-handled hoe performed better in the timed trials, most subjects preferred the new short-handled hoe due to familiarity. Consistent with innovation diffusion theory, only some (innovators and early adopters) readily adopted the long-handled hoe as their method of choice. Sustained efforts would be needed to make it available and promote its use more widely among women vegetable farmers in Africa.

Introduction

While modern mechanized agriculture has eliminated much of the manual work in many sectors, vegetable production throughout the world still involves hazardous repetitive manual labor (Fathallah et al., 2008). This type of labor presents multiple physical risk factors for musculoskeletal discomfort/disorders (MSDs) and injuries (Janowitz et al., 2000; Fathallah et al., 2008). Data from vegetable production in the USA show that MSDs are, in fact, the most commonly reported occupational outcome of migrant vegetable farm workers (Villarejo & Baron, 1999) and that occupational injuries are a very common problem of vegetable farm workers (NIOSH, 2001).

Vegetable production is a very important activity in countries such as The Gambia, a small West African country, engaging 42% of the total working population, most of whom are women with little education or financial resources (Carney, 1998; Culp et al., 2007). However, little research has been conducted on occupational health and worker productivity issues in labor-intensive vegetable farming in developing countries, particularly among female workers (FAO/IFAD, 1998).

In our preliminary study (Vanderwal et al., 2009), women vegetable farmers in The Gambia stated that land preparation was the most injury-prone task in the garden, required long hours of heavy physical labor, and was very painful. This has been confirmed by other researchers (Kuye et al., 2006a; O'Neill, 2000; Nag & Nag, 2004). Some studies have evaluated the use of different hand hoes in land preparation, but these studies had small numbers of subjects, and often involved only male subjects (Badiger, 2006; Tewari et al., 1991; Nwuba & Kaul, 1986). Some studies have suggested that long handled hoes are more productive than short-handled hoes, but few have evaluated worker discomfort, injury risks, or long-term worker acceptability and use (Rogan and O'Neill, 1993).

Few studies have involved farmers, particularly women farmers, in the development and/or selection of tools used in intervention studies in which they are involved, although this is essential for the success of the study (Kaul, 1993; Rogan and O'Neill, 1993; Egharevba & Iweze, 2004). Accordingly, we used a community participatory research approach (Vanderwal et al., 2009) to discuss the task of land preparation and the locally-made tools the women vegetable farmers normally use (see Figure 3.1). We then demonstrated new hoe models (n=14), and allowed the subjects to select one short-handled (which was purchased locally) and one long-handled (shipped from the USA) hoe to test, which were then replicated locally for our trial.

The specific aim of this study was to evaluate the effectiveness of interventions (long- and short-handled hoes) for land preparation among women vegetable farmers in The Gambia, as well as to identify barriers and enabling factors essential for long-term sustainability of the interventions. The specific hypothesis driving this research was that compared to traditional work methods, interventions chosen in a participatory manner will:

a. increase worker productivity;
b. decrease work-related musculoskeletal discomfort and injury risk indicators; and

c. gain long-term acceptance and increased use among the participants after the initial trials.

Figure 3.1. Subject using a traditional hoe during the land preparation trial

This study was designed as a mixed-methods study (Creswell et al., 2003). We used quantitative methods to describe worker productivity, discomfort and injury risk indicators, and some indicators of long-term worker acceptance of the interventions, through timed trials and individual interviews. To compliment these data, qualitative individual interviews, focus groups, and observations were also conducted to identify barriers and enabling factors that are essential for long-term sustainability of the interventions.

Methods

Experimental design

The study used a modified repeated treatment design to gather data, utilizing the overall experimental design illustrated in Figure 3.2.

Figure 3.2. Study experimental design

Intervention Selection		**Intervention testing**								**Follow up**
	Group A	X	O_t	-	O_t	X	O_t	-	O_t	
O_{fg} O_{fg}										O_{fg} O_{ii} O_{fg}
	Group B	-	O_t	X	O_t	-	O_t	X	O_t	

O_{fg} = Focus group observation (conducted jointly with both groups)
O_{ii} = Individual interview observation
O_t = Observation during trials (monitoring and interviews)
X = Use of intervention method in trials
\- = Use of traditional method in trials
Subjects were randomly assigned into Group A or B for the intervention testing trials.

Setting

The vegetable garden where this research was conducted is located 1.2 km east of the village of Gunjur, in the Western Region of The Gambia, in West Africa. The garden was established and is overseen by a local non-governmental organization (NGO), the Trust Agency for Rural Development (TARUD). TARUD employs a local garden advisor, who also served as the main liaison between the research team and the subjects and the main assistant for the principal investigator (PI) of the study. The PI developed significant connections with the leadership of the garden, which enabled strong commitment among subjects and project assistants to participate in the study. More detailed information on the country of The Gambia, the garden where the study was conducted, and the overall implementation of this body of research is available in an earlier publication (Vanderwal et al., 2009).

Subjects

A total of 212 women work in the garden, each in her own plot. The women are divided into twelve workgroups, with a leader in each group. In addition to the leader of the group, three other women from each group were randomly selected to take part in the study. The PI and the local project assistants met with these 48 subjects to introduce the study, explain the subject eligibility requirements (aged 18 years or over and currently actively engaged in vegetable farming) and administer informed consent in the local language, as approved by the Government of The Gambia Human Ethics Committee (SCC/EC #1123) and the University of Iowa Institutional Review Board (IRB ID# 200808704). All selected women agreed to participate in the study. All subjects were provided with a small monetary incentive for their participation, which was not made known to the participants until the end of the study when the compensation was distributed.

Development of the interventions tested in the study

After the women consented to participate in the study, a participatory focus group discussion was held (in Mandinka, the local language) at the vegetable garden, with the leaders from the twelve garden workgroups, as described by Vanderwal et al. (2009). All focus groups in this study lasted approximately 1-1.5 hours and were conducted at the vegetable garden, digitally recorded, and hand-written notes were also taken by the PI. This participatory approach is similar to methods used in a number of intervention studies, including in labor- intensive agriculture (Meyers et al., 1997; Baron et al., 2001; Earle-Richardson et al., 2005). The participants discussed the tools, timing, safety and work efficiency concerns they have in the various tasks of vegetable gardening, including land preparation. The investigator provided models of various types of hoes (n=14) that were readily locally-reproducible, and encouraged the subjects to generate ideas of other types of hoes or modifications to existing hoes that could improve the task of land preparation. The different tools were left with the subjects for one week to test, after which a second focus group was held to discuss and select the hoe models (one short-handled hoe and one long-handled hoe) they would like to utilize in the study. Research team members also observed the subjects during their regular work and conducted targeted interviews with key informants to augment the information gathered in the focus groups. The Gambian National Agricultural Research Institute (NARI) engineering unit was contracted to manufacture 12 copies of both hoes to be used in the study, at a cost of approximately 6 USD per hoe. Due to the local conditions under which the tools were produced, the replicated tools used in the study were slightly different than the models they were based upon (see Table 3.1).

One week before the initial trials occurred, the intervention hoes were brought to the garden and further demonstrated to the subjects. The subjects were encouraged to use the hoes in their routine land preparation tasks to accustom themselves to the intervention tools. See Figures 3.3 and 3.4 for photos of the hoes used in the study, as well as the models they were based upon.

Figure 3.3. Traditional hoe, representative of those tested in the study

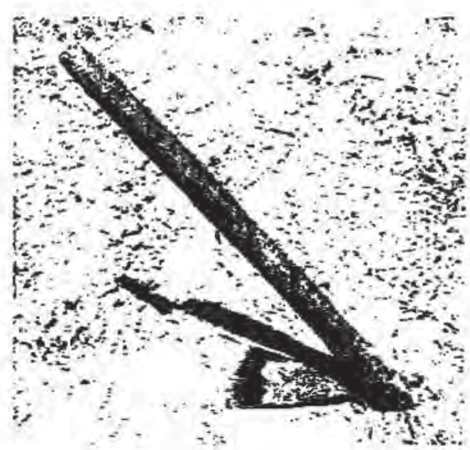


Figure 3.4. Intervention hoes tested in the study. The model hoes are on the outside, with the locally-manufactured short and long-handled hoes in the center. Note that the handle of the model long-handled hoe had to be cut for shipping from the US.

Table 3.1. Average specifications of hoes used in the study

Characteristic	Traditional hoe*	Model short hoe	Short hoe used in study	Model long hoe†	Long hoe used in study
Weight of hoe (grams)	530	500	600	1200	1000
Length of handle (cm)	48	45	49	145	141
Length of blade - from handle insertion to flat cutting edge (cm)	17.5	19	18	20	19
Blade width- flat cutting edge (cm)	7	9.5	10	10	10.5
Circumference of handle (cm)	9.5	8.5	11	9.4	11
Angle of blade (compared to handle)	60°	75°	80°	85°	90°

*The traditional hoes used in the study varied greatly, as each subject used their own hoe, made by different local blacksmiths. The listed values are based on a number of hoes.

†Note that the model long-handled hoe had a metal tube to join the handle back together, which weighed about 200 g alone.

Data collection methods

Data collection instruments

All data collection instruments were developed in English with extensive input from the research team in the USA, as well as local research team members, to ensure proper translation and understanding in the local language. In particular, Dr. Rex Kuye, the Gambian member of the research team who had conducted similar research on injuries in farmers in The Gambia (Kuye et al., 2006b), provided a great deal of insight into the content and design of the data collection instruments. The officials with the local NGO overseeing the garden also provided a great deal of input to the data collection instruments and study methodology, based on their numerous years of experience working with the women in the garden. Note also that although the PI of the study could only speak and understand basic Mandinka, a third party (not part of the garden leadership structure or directly assisting with the research) bilingual Gambian accompanied the PI during most of her time in the garden. This person could explain the content of the various discussions and interviews and could check for the interpretation of the questions. This person was typically either a local public health officer or a bilingual driver.

Interviewers

Selected students from an Occupational Health course, taught by the PI, at the School of Public Health at The Gambia College in Brikama were trained to serve as project assistants and interviewers, at the suggestion of Dr. Kuye and the approval of the leadership of the garden. Interviewers were trained extensively on research principles in occupational health, dealing with human subjects, terminology used in the data collection instruments, and the appropriate translations into the local language. Interviewers practiced administering the questionnaires to other students in the class numerous times, and modifications were made to the data collection forms as necessary based on these practice sessions.

Interviewers were also trained to use the heart rate monitors (Reebok Precision Trainer XT Heart Rate Monitor with Chest Strap) and timers used in the study. All interviewers were fluent in the local language of Mandinka, and were familiarized with local expressions used in the village where the research was conducted. Of the 12 interviewers working in the initial trials, three were female, four had worked previously as nurses in similar rural villages, one served as a nurse in the village of Gunjur for four years, one student was originally from that village, and many others were from nearby villages.

Implementation of initial trials

Biographical data were collected from the subjects through individual interviews in the local language. Environmental data (air temperature and humidity) were collected every hour during the trials, using an Oregon Scientific WMR 968 portable, cable-free weather station.

Areas of land in the garden that required land preparation were identified, and then divided into 4 equal plots for each subject to use in the trials. The plots ranged in size from 5-8 meters^2. Great care was taken to ensure that all 4 plots for each subject were the same size, level of weediness, moisture content, soil type, and generally equal in terms of ease/difficulty of land preparation. Subjects were then fitted with the chest strap and wrist display of a heart rate monitor. Each subject was then asked to till one of their marked plots of land, using either her traditional hoe, the short-handled intervention hoe (new short), or the long-handled intervention hoe (new long) (see Figure 3.5). After tilling each plot of land, the interviewers recorded the length of time required for the subject to till each plot of land, as well as the subject's average and maximum heart rate during that trial.

Figure 3.5. Subject using the long-handled hoe in the land preparation trial. Note the prepared ground behind her, with land requiring preparation in front of her.

After tilling every plot of land, the subjects were asked questions from the structured questionnaire regarding their discomfort in each of four body regions (neck/shoulders, arms, lower back, legs) in the just-completed trial. Each subject was also asked if they incurred any injuries or had any near misses in that trial, and about their feelings of safety and ease of use during that trial. For discomfort in the various body regions, the subjects were asked to point to their level of comfort or discomfort on a 5-point hedonic scale consisting of a series of 5 faces (Peterson, 2000), drawn by one of the Gambian interviewers and approved by Dr. Kuye and the garden leadership. The 5 faces ranged from very uncomfortable (unhappy - on the left of the scale) to very comfortable (happy - on the right).

Each subject used the traditional hoe in 2 of their plots and either the new long or new short hoe in their other 2 plots. The same type of information that was obtained after completion of the first plot was also collected after the subject finished each of her 4 plots. As much as possible, the subjects were randomized into using either the traditional hoe or one of the intervention hoes on the first plot. Subjects were asked to alternate back and forth between the traditional and intervention hoes in subsequent trials. Subjects were generally randomized into using either the new long or new short hoe as the intervention in the trials, although in some cases, subjects selected which intervention hoe they wanted to use.

The interviewers were asked to observe the subjects during the trial for any unusual circumstances that may have occurred during that working phase that would dramatically change the subjects' work productivity, discomfort, or injury risk. The subjects were encouraged to till each plot to the same depth, with the same quality of tillage, which was monitored by the interviewers. The interviewers also recorded if the subject had a baby on her back or if she was wearing closed toed shoes or any other protective equipment during the trial. Qualitative feedback from the subjects on the hoes used in the trial was also recorded by the interviewers.

The subjects were encouraged to continue to use both intervention hoes in their routine work in the garden and to recall their experiences and perceptions of the hoes until the next data collection exercise. The PI also observed the subjects whenever she went to the garden, throughout the entire study.

One-month follow-up focus groups

One month after the initial trials, a focus group discussion was held, primarily with the twelve leaders of the garden workgroups participating, although all subjects were welcome to attend. The participants were asked for their perceptions of the interventions, their rationale for these thoughts, how much they have been using the interventions and why, any injuries or near misses, and the reaction of others to their use of the intervention hoes. The follow-up focus group discussions were conducted in a similar way to those held to select the interventions used in the study, as described in Vanderwal et al. (2009). Subjects were again encouraged to continue to use both intervention hoes in their routine work and to recall their experiences and perceptions of the hoes until the next data collection exercise.

Two-month follow-up individual interviews

Two months after the initial trials, individual interviews were conducted with all the subjects, using six of the same interviewers that were used in the initial trials. All the women that participated in the initial trials also participated in the follow-up individual interviews (100% retention rate). Each subject was asked questions with a range of pre-determined answers on how much time they have been using the hoes, if the hoes were available to them, any injuries or near misses, and their thoughts on which hoes were safer, easier, faster, and which they preferred to use. Subjects were asked to compare the traditional hoes to the new hoes, as well as the long-handled to the short-handled hoe. Subjects were also encouraged to provide qualitative feedback on why they preferred the different types of hoes and any suggestions they had to improve the hoes.

Three-month follow-up focus groups

Three months after the initial trials, a final focus group discussion was held, in the same manner and with the same basic questions as in the one-month follow-up discussion. Twelve subjects were randomly assigned to take part in the discussion group on land preparation. Subjects were also asked in which tasks they use the new long and new short hoes and any suggestions they had to improve the hoes.

Data analysis

Statistical analysis of quantitative data

Generalized Estimating Equations (GEE) was used as the primary regression analysis procedure (Zeger & Liang, 1986; SAS Institute Inc., 2008). GEE was used to calculate the mean values for each type of hoe for the continuous outcomes, including: a) time required for the trial; b) average heart rates; and c) maximum heart rates, and to compare the mean values by the type of hoe used to the other types. Potential confounding factors/ affect modifiers for each outcome were identified using univariate modeling in GEE, and interaction terms were created and tested between those variables significant at the $P < 0.05$ level in univariate analysis.

Unadjusted odds ratios and 95% confidence limits were calculated (using GEE) for each dichotomized outcome (discomfort in various body areas and injury near misses), comparing the various land preparation methods used to each other. Those independent variables that were significant at the $P < 0.05$ level for at least one dichotomized outcome and those variables shown to be covariates in previous studies were used in the multivariable modeling of the dichotomized outcomes.

Logistic regression analysis was used to identify factors that had a significant association with the outcomes reported in the two-month follow-up individual interviews. We also used Fisher's exact test to compare the injury near misses between the different types of hoes in the two-month follow-up data.

For the GEE analysis, the logit link function was utilized for binomial outcomes, with the identity link function used for the continuous outcome variables. Subject identification number was used as the clustering factor to enable repeated comparisons of the same subject using the different intervention methods, which was the primary independent variable of interest. GEE analyses were performed using PROC GENMOD in SAS Version 9.2 (SAS Institute Inc., 2009).

Analysis of qualitative data

All the information gathered through the various qualitative data collection methods (focus groups, observation, and individual interviews) was analyzed to identify patterns and common themes, with the primary objective of discovering theory explaining subjects' attitudes and behavior with the different types of tools. This process is based on grounded theory (Glaser & Strauss, 1967) and entails the simultaneous processes of data collection, analysis, and theory construction. All qualitative data were recorded on open-ended forms and focus group discussions were digitally recorded. The PI worked with the local project team and the focus group facilitator to understand the focus group data both during and immediately after the discussions. All opinions expressed by subjects were included in the analysis, with particular attention given to the number of subjects reporting a particular point.

Results

Quantitative findings

Subjects

The main demographic characteristics of the forty-eight Gambian women participating in the study are indicated in Table 3.2.

Table 3.2. Characteristics of subjects (n=48)

		Range	
Characteristic	**Mean**	**Min**	**Max**
Height (m)	1.60	1.50	1.73
Weight (kg)	58.7	40	90
10-year age range	40-49 years	18-29 years	80-89 years
Years garden experience (category)	6-10 years	1-5 years	> 20 years

Most (96%) subjects were of the Mandinka tribe, although all subjects spoke the Mandinka language fluently. The majority of the women (79%) reported that they were right-handed, with 19% reporting that they used both hands equally, and 2% reporting that they were left-handed. Only 25% of subjects reported that they were the only wife of their husband, with most women (75%) reporting that their husband had multiple wives. Of those subjects in polygamous marriages, 50% were the first wife, with 42% being the second wife and 6% the 3rd wife of their husband. All the women reported having malaria at some point in their life, but only 6% (n=3) of women reported that they were admitted to the health center for their most recent case, with an average stay of 3 days. Only one subject indicated she thought she was pregnant, in her first trimester. There were only 2 trials where a subject had a baby on her back, each time for less than half of the trial. The subjects were either barefoot or wore light rubber sandals ("flip-flops") in all the trials.

Quantitative outcomes of initial trials

As shown in Table 3.3, when compared to using the traditional hoe, subjects were able to till plots of land using the new long hoe in 22% less time ($p= 0.01$), while use of the new short hoe took 20% more time ($p=0.05$). Compared to using the new short hoe, the new long hoe took 35% less time ($p < 0.01$). Subjects worked to about the same average heart rate for all methods, but worked to a 5% lower maximum heart rate ($p=0.02$) when using the new short hoe, compared to the traditional hoe. When conducting univariate data analysis for factors that influence changes in the time required for the trial, the variables of humidity, average and maximum heart rates, and the method used were all significant ($p < 0.05$). For changes in average heart rate, subject height, age, and time required for trial were found to be significant at the $p < 0.05$ level. For maximum heart rate, the method used, soil temperature, time of trial, and average heart rate were significant ($p < 0.05$) in univariate analysis.

After each trial, subjects reported on their level of comfort or discomfort (on a five-point scale) in four body regions as well as injuries and near misses. Those subjects indicating either great discomfort or discomfort (the first or second face on the scale) were considered as having discomfort and those reporting they were neutral (middle face) or comfortable (fourth and fifth faces) were considered as not having discomfort. The percentage of subjects reporting discomfort is reported in Table 3.4. No injuries were reported in the trials, but subjects reported to have injury near misses in 40 trials.

Table 3.3. Mean values of continuous outcomes by each method used in the land preparation trial

	Mean values, by method used			P-values* of comparison				
	New Long	New Short	Tra-ditional	New Long	New Short	Traditional	New Long	New Short
Time required (seconds)	231.4	353.1	295.4	**0.01**	**0.05**	*reference*	**<0.01**	*reference*
Average Heart Rate (bpm)	129.5	127.5	130.0	0.86	0.37	*reference*	0.69	*reference*
Maximum Heart Rate (bpm)	143.3	136.3	143.4	0.97	**0.02**	*reference*	0.15	*reference*

bpm= beats per minute

*GEE was used to calculate p values; p-values are in comparison to reference listed directly after that value

When conducting univariate analysis on characteristics influencing discomfort in each of the body regions and for injury near misses in these trials, the variables of subject age, height, weight and method of land preparation were significant at the $p < 0.05$ level for many outcomes. These variables have been shown to be risk factors in other studies on body discomfort among African farmers (Maruka, 1998; Fabunmi et al., 2005; Naidoo & Haq, 2008), and thus were included in the adjustment of the discomfort and near miss outcomes by land preparation method in Table 3.4. The time required for the trial was not a significant predictor of discomfort in any body region. The consecutive trial number (1, 2, 3 or 4) was also not a significant predictor of any outcome in this study, which indicates that there was no effect of a "learning curve" for the subjects in using a new tool for the first time.

As shown in Table 3.4, compared to the traditional hoe, the new long hoe reduced the odds of subjects reporting discomfort in the lower back, hips and legs, and also of reporting an injury near miss. The estimates and confidence intervals changed very little in the multivariable models, indicating that the effect of the covariates was marginal. Using the new long hoe also reduced the odds of neck and shoulder discomfort, and arm and hand discomfort, but it was not significant in either the univariate or adjusted models. The odds of subjects reporting arm and hand discomfort was significantly higher with the new short hoe, as compared to the traditional hoe. Compared to use of the new short hoe, the new long hoe significantly reduced the odds of reporting discomfort in all body regions, as well as for injury near misses.

Quantitative outcomes of two-month follow-up interviews

Two months after the initial trials, 25% of subjects reported that they had not used the new long hoes at all since the initial trials, 20 of 48 subjects reported that they had used the new long hoes 25% of their time, and 11 subjects reported using them 75% of their time in land preparation. In contrast, 29 of 48 subjects reported using the new short hoes 75% of their time in land preparation since the original trials, with 8 women using the new short hoes 25% of their time in land preparation. More than half of the women reported that they could use the new long (51% of subjects) or new short hoes (54% of subjects) anytime they like, with approximately 25% of women reporting that they have to ask to use the new long (26.7% of subjects) or short (29%) hoes, but they receive them immediately upon asking.

No injuries were reported with any hoes in the two months after the initial trials. Only one (1) subject reported an injury near miss when using the new long hoe, significantly less than near misses reported with the traditional hoe (n=8, Fisher's exact $p= 0.03$). Three (3) subjects reported a near miss when using the new short hoe, which was not significantly different than with the traditional hoe (Fisher's exact $p= 0.19$).

Table 3.4. Association of intervention method with discomfort and injury outcomes

				Unadjusted values			Adjusted* values		
Outcome	Intervention method	N=	% discomfort‡	Odds Ratio	Lower CL	Upper CL	Odds Ratio	Lower CL	Upper CL
Neck and shoulder discomfort	New Long	43	26%	0.44	0.19	1.05	0.46	0.19	1.13
	New Short	53	51%	1.34	0.73	2.46	1.29	0.69	2.43
	Traditional-reference	94	44%	-	-	-	-	-	-
Arm and hand discomfort	New Long	43	23%	0.45	0.19	1.03	0.49	0.20	1.20
	New Short	53	57%	**1.92**	**1.12**	**3.31**	**1.88**	**1.07**	**3.28**
	Traditional-reference	94	40%	-	-	-	-	-	-
Lower back discomfort †	New Long	43	16%	**0.19**	**0.07**	**0.50**	**0.20**	**0.07**	**0.56**
	New Short	53	45%	0.79	0.46	1.36	0.76	0.44	1.31
	Traditional-reference	94	51%	-	-	-	-	-	-
Hip and leg discomfort †	New Long	43	14%	**0.22**	**0.08**	**0.63**	**0.21**	**0.07**	**0.63**
	New Short	53	36%	0.75	0.42	1.35	0.69	0.38	1.26
	Traditional-reference	94	43%	-	-	-	-	-	-
Injury near miss	New Long	43	9%	**0.33**	**0.13**	**0.83**	**0.33**	**0.13**	**0.84**
	New Short	53	26%	1.19	0.70	2.03	1.10	0.59	2.04
	Traditional-reference	94	23%	-	-	-	-	-	-

* All values were adjusted for age and height

† Outcomes were also adjusted for weight, in addition to age and height

‡ Indicates the % of trials for that method where subjects reported discomfort. For the injury near miss outcome, indicates the % of trials reporting an injury near miss.

When combining the subject responses of "definitely new" and "probably new" (shown in Table 3.5), nearly all subjects indicated that they felt the new hoes (both long and short-handled) were safer (81%), easier (94%), faster (92%), and were preferred (94%).

Table 3.5. Comparison of subject perception of new (both long and short-handled hoes) to traditional land preparation methods, two months after initial trials

	Frequency of persons reporting					
	definitely traditional	probably traditional	both the same	probably new	definitely new	TOTAL
Safer	1 (2%)	0 (0%)	8 (17%)	14 (29%)	25 (52%)	48
Easier	2 (4%)	1 (2%)	0 (0%)	14 (29%)	31 (65%)	48
Faster	2 (4%)	0 (0%)	2 (4%)	11 (23%)	33 (69%)	48
Prefer	2 (4%)	1 (2%)	0 (0%)	12 (25%)	33 (69%)	48
TOTAL	7 (4%)	2 (1%)	10 (5%)	51 (27%)	122 (64%)	192

*The percentages listed immediately after the frequency counts are expressed as the % of the total for that row (listed in the far right column).

When comparing the short to long-handled hoes, more subjects indicated that they thought ("definitely" or "probably") that the short-handled hoe was safer (63%), easier (80%), faster (81%), and preferred (75%), as indicated in Table 3.6. Some subjects did feel ("definitely" or "probably") that the long-handled hoe was safer (27%), easier (15%), faster (16%), and preferred (19%).

Table 3.6. Comparison of subject perception of new long-handled to new short-handled hoes for land preparation, two months after initial trials

	Frequency of persons reporting					
	definitely short-handled	probably short-handled	both the same	probably long-handled	definitely long-handled	TOTAL
Safer	22 (46%)	8 (17%)	5 (10%)	2 (4%)	11 (23%)	48
Easier	30 (63%)	8 (17%)	3 (6%)	1 (2%)	6 (13%)	48
Faster	34 (71%)	5 (10%)	1 (2%)	3 (6%)	5 (10%)	48
Prefer	25 (52%)	11 (23%)	3 (6%)	1 (2%)	8 (17%)	48
TOTAL	111 (58%)	32 (17%)	12 (6%)	7 (4%)	30 (16%)	192

*The percentages listed immediately after the frequency counts are expressed as the % of the total for that row (listed in the far right column).

Qualitative findings -- barriers and enabling factors

essential for long-term sustainability of interventions

From the qualitative responses in the individual interviews in the initial trials and in the two-month follow-up, the two follow-up focus group discussions, and subject observation, we identified various barriers and enabling factors essential for long-term sustainability of the interventions used in the study, summarized in Table 3.7 and further explained below. Note that all quotations from subjects are translated into English from the local language of Mandinka.

Table 3.7. Summary of themes in qualitative findings

	Intervention hoes (vs. traditional hoes)	**Long-handled hoe (vs. short-handled hoe)**
Barriers	- Increased weight of the new hoes - Lack of familiarity - Unavailability of intervention hoes	- Lack of familiarity - Long-handled considered less versatile - Perceived to be slower - Handle breakage
Enabling Factors	- Less discomfort when using - Increased productivity - Strength and durability - Improved safety - Time for adjustment - Novelty - Approval of men and other villagers	- Less discomfort when using - Improved safety - Quality of tillage - Novelty - Increased work efficiency

<u>Barriers to long-term sustainability of intervention</u>

<u>(both long and short-handled) hoe use</u>

Increased weight of the new hoes

In the individual interviews, subjects reported that the heavier weight of the intervention hoes made it more difficult to carry them to the garden and to work with once in the garden. Multiple subjects reported that they would like the intervention hoes to be lighter, but to maintain their strength.

Lack of familiarity

Subjects in the focus groups and the interviews indicated that they have been using the traditional hoe for many years, and many find it easier to continue in their current manner rather than to change their working patterns and postures. One subject stated in an interview that "*the traditional hoe is much easier since we are used to it*".

Unavailability of intervention hoes

A limited number of intervention hoes were brought to the garden (12 long-handled and 12 short-handled for 48 subjects), so in the interviews and focus groups, subjects said that many people were sometimes waiting to use the new hoes, and subjects didn't want to wait to get an intervention hoe from others. One participant in the one-month focus group stated that "*we would use the new hoes all the time if we each had one*", and another that "*(we) only use traditional hoes if no new ones are available*". Research team members observed that the 12 group leaders control the new hoes, thus the other participants needed to ask the group leaders to use the hoes, which is not possible if the group leaders are not present at the garden or are using the new hoes themselves.

Enabling factors for long-term sustainability of intervention
(both long and short-handled) hoe use

Less discomfort when using

One member of the three month follow-up focus group stated: "There are pains, as long as you are working, irrespective of the tools used. (There) seems to be less pain with the intervention hoes than the traditional." Other subjects also reported that the intervention hoes reduced discomfort in the back, neck and hands after working, particularly with the reduction in bending with the long-handled hoe. The improved quality and larger circumference of the intervention hoe handles were also cited in interviews and focus group discussions as reducing discomfort.

Increased productivity

Some subjects in the interviews and focus groups noted that the larger blade area of the intervention hoes increased productivity and ease of tillage, and that the 2 ends of the hoe blade area (wide, flat edge and pointed end) can be used easily for different purposes. Our observations also confirmed that subjects would use the wide, flat end for tilling large areas and then rotate the handle to use the pointed end for breaking up large soil clumps or getting into smaller areas. One subject noted in the interviews immediately after the initial trials that the traditional hoe blade sometimes comes off and needs to be reattached, which slows their work. Subjects in focus groups and interviews noted that less labor is required when using the new hoes, compared to the traditional hoes, partially because the heavier weight causes the hoe to dig deeper with less required force. The research team noted that the quality of work with the new hoes was also improved as the women were able to dig about 1.5-3 times deeper in the soil with the new hoes than the traditional hoes, which the subjects also confirmed in the follow-up focus groups and interviews. Some subjects in the focus groups also stated that the new hoes were sharper and could more easily remove the roots of weeds than the traditional hoe.

Strength and durability

In the focus group discussion one month after the initial trials, some subjects noted that they had adjusted to the increased weight of the intervention hoes and felt that this made the hoes stronger. Many subjects in interviews noted that if the intervention hoes could be lighter, but strong, with lighter metal and stronger wood, they would "*definitely use*" the intervention hoes.

Improved safety

Because of the improved quality and circumference of the intervention hoe handles, and the increased length of the long-handled hoe, subjects cited in the individual interviews that the intervention hoes are less likely to slip out of their hand and cut them on the leg.

Time for adjustment

Subjects in the one-month focus group felt that they would eventually get used to the new methods and that the new hoes may get lighter with time as the wood handles dry, thus losing the weight of the water, and the metal may chip away. Subjects also noted that it was "*not difficult to learn how to use the new hoes as they are similar to our traditional hoeing method*".

Novelty

When given a list of four possible choices and the opportunity to provide qualitative feedback as to why they preferred the new (or traditional) hoes in the two-month follow-up individual interviews, eight subjects selected the option that they preferred the new hoes as they "*liked to try new things*". One other subjected noted that she didn't want to waste something new that was given to them.

Approval of men and other villagers

The village men did not give any negative feedback to the subjects on their use of the new hoes, and were generally supportive of their new working methods, according to the focus group discussions. The subjects stated in the focus group discussions that other village women, particularly those working in nearby vegetable gardens would also like to have new strong hoes.

Barriers to long-term sustainability of long-handled

(compared to the new short-handled) hoe use

Lack of familiarity

Similar to the comparison of the new to the traditional tools, all the qualitative findings strongly indicate that subjects are accustomed to using the short-handled hoe, and so prefer to continue to work in the same fashion. Some subjects in the one-month focus group said that they prefer the new short hoe, but would use the new long hoe if the new short hoe was not available. In the 3-month follow-up focus group, subjects noted that the new long hoe "*feels strange at first, so don't feel productive at first, but may feel productive later*".

Long-handled hoe considered less versatile

Many subjects reported in interviews and focus groups and the research team observed that subjects used the new long hoes primarily for land preparation, which typically lasts mainly for a few weeks each growing season, and occurred at the beginning of the study. Short handled hoes are considered to be better for weeding, which is done throughout the year. Subjects in the focus groups feel that the long-handled hoe is not as precise as the short-handled hoe in weeding, and the research team observed that the subjects tend to use their free hand to remove weeds or debris when using the short-handled hoe, which is not as easy when working in an upright position with the long-handled hoe. Also, some subjects in the interviews after the initial trials feel the short-handled hoe is more useful than the long-handled hoe when the ground is dry and hard. One subject in the one-month focus group stated that the "*short-handled hoe can be used in many places and for many uses*".

Perceived to be slower

In some individual interviews and in the 3-month follow-up focus group, some subjects stated that using the new short hoe is faster and easier than the new long hoe. One subject mentioned that "*bending (when hoeing) is faster and easier*".

Handle breakage

During the initial trials, the handles of 3 long-handled hoes cracked, compared to only 1 short-handled hoe breaking. One more handle of a long-handled hoe broke before the 3 month follow-up focus group discussion. The research team observed that the subjects tend to lift the hoes above horizontal and force them down, and that the intervention hoe handles are made from a soft, locally available wood, which may be more likely to break. Some subjects noted in their interviews that it would be beneficial for the long-handled hoes to be made with lighter metal and a stronger wood handle, to improve its long-term sustainability.

<u>Enabling factors for the long-term sustainability of long-handled (compared to the new short-handled) hoe use</u>

A few subjects were very satisfied with the long-handled hoe, with one subject stating in the individual follow-up interviews that "*in all aspects I prefer the long handled hoe.*"

Less discomfort when using

It was well-recognized by subjects in the interviews and focus groups that using the long-handled hoe reduced the need for bending, so reduced back discomfort. One subject noted in the initial trials that when using the long-handled hoe, she could "*stand up immediately after work*" and another that "*I do not feel so much pain when using the long-handled hoe.*" Even subjects that prefer to start working with the short-handled hoe recognized that the long-handled hoe reduced discomfort, by stating that they "*can use the long handled hoe if you are tired with the short-handled hoe*."

Improved safety

Some subjects in the focus group discussion noted that the upright working position with the long-handled hoe allowed them to keep their hands away from the soil where scorpions, snakes, and abrasive objects may reside. The PI observed that the long-handled hoe also moved the hoe's soil contact area further from the subjects' feet, thus reducing the likelihood of injuries from the hoe hitting the feet. One subject noted in the interviews after the initial trial that the "*long handled hoe cannot easily wound*".

Quality of tillage

During the initial trials, the interviewers noted that subjects tilled the soil about 1.5 times deeper with the long-handled hoe than the short-handled hoe. Some subjects noted in the interviews after the trials that the long-handled hoe was useful particularly when the soil is moist and easier to till.

Novelty

Similar to the comparison of new and traditional methods, two subjects in the two-month interviews said that they preferred the long-handled hoes as they "*liked to try new things*".

Increased work efficiency

One subject in the three-month follow-up focus group noted that the long-handled hoe is more efficient as a larger working area can be reached from one standing location, reducing the need for subjects to move from place to place in the plot to till more ground.

There were no significant relationships found between any of the subjects' qualitative responses and the subject's age, height, weight, garden experience, or any other variable.

Discussion

The results of this study demonstrate the importance of using multiple methods to rigorously evaluate the utility of interventions to improve worker productivity, health, and safety, particularly of farm workers in Africa. Many times, well-meaning organizations provide interventions intended to improve the lives of the beneficiaries, but the interventions may not have been adequately evaluated for usefulness, acceptability, sustainability, or possible negative effects (Aubel & Samba-Ndure, 1996). Further, research studies which have evaluated new agricultural hand tools have mainly addressed only worker efficiency (Rogan & O'Neill, 1993; Nwuba & Kaul, 1986), or changes in injuries, muscle pain, work postures, or other factors which are important, but do not provide a complete picture of the value of the intervention on their own (FAO/IFAD, 1998). Therefore, it is essential that many of these factors are considered together in order to evaluate the long-term sustainability of the interventions.

Two months after implementing the interventions, 94% of subjects said they prefer the new hoes, a preference which was strongly reinforced by both the quantitative and qualitative findings. The new long-handled hoe proved to be significantly faster and caused less body discomfort and injury near misses than the traditional hoe. A number of key enabling factors for the long-term sustainability of the intervention hoes were identified from the qualitative findings, as listed in Table 3.7. Although most subjects preferred the intervention hoes, some barriers were also identified.

The average heart rates in this study were nearly the same for all methods (128-130 bpm) and comparable to those reported in similar hoeing trials with women (144 bpm - Nag & Chatterjee, 1981; 103-135 bpm - Chatizwa, 1997). Subjects were willing to work to the same maximum heart rate (Max HR) with the new long hoe as with the traditional hoe, but completed the same task in a much shorter time with the new long hoe. Subjects reduced their work pace, indicated by lower Max HR, with the new short-handled hoe, possibly due to localized stress, thus also increasing the amount of time required to till the same area of land. Compared to the traditional hoe, subjects reported more arm and hand discomfort when using the new short-handled hoe. Therefore, it is possible that this discomfort caused subjects using the new short hoe to reduce their working pace.

Use of the new long-handled hoe significantly reduced the time required to till an equal area of land, both compared to the traditional hoe, and particularly to the new short-handled hoe. This is consistent with other studies (Nwuba & Kaul, 1986; Chatizwa, 1997; Badiger, 2006). However, in the two-month follow-up individual interviews, 81% of subjects thought the short hoe was faster, compared to only 16% saying the long hoe was faster.

In the qualitative responses, some subjects stated that they feel bending and using the short-handled hoe is faster than using the long-handled hoe. Subjects also heavily emphasized that they were accustomed to using a short-handled hoe, so they feel more comfortable with it, and likely thus <u>feel</u> more productive when they use it. One subject did note that a larger working area can be reached from one standing location with the long-handled hoe, reducing the need for subjects to move as much from place to place in the plot to till more ground. Therefore, subjects may feel like they are working more slowly with the long-handled hoe because they are not moving their body around as much or as fast to complete the same amount of work, compared to using a short-handled hoe.

A recent review by Fathallah et al. (2008) confirmed that lower back discomfort is a common outcome among vegetable farmers in both developed and developing countries. In our study, use of the new long-handled hoe reduced discomfort in the lower back, and hip and leg regions, as well as injury near misses. The difference was significant when compared to the traditional hoe, and even more striking when compared to the new short-handled hoe. Other studies have also demonstrated that a longer hoe handle reduces back pain and increases worker acceptance (Ramahi & Fathallah, 2006; Chatziwa, 1997). Because of pain associated with their use, the state of California in the

USA banned the use of short-handled hoes (<1.2 meters length) in labor-intensive agriculture in 1975 (CDIR, 2005).

Despite the clearly positive results in the initial trials for the long-handled hoe, the two-month follow-up interviews and other qualitative findings showed that most subjects preferred the short-handled hoes over the long-handled hoes. The barriers identified in the qualitative findings offer a number of explanations for this apparent reversal from the quantitative results of the initial trials:

1. Subjects are accustomed to using short-handled hoes and working in a stooped position, so they feel more comfortable and productive when using the short-handled hoe. The long-handled hoe is also heavier than the new short-handled hoe, which is similar in weight to the traditional hoe.
2. The long-handled hoes were perceived to be useful mainly in land preparation, occurring mainly in a 2-week period early in the growing season (which took place at the beginning of the study). Short-handled hoes, on the other hand, were considered more accurate and efficient in weeding (which is done year-round), and more useful in preparing hard, dry ground. Even though all questions in the study explicitly referred to land preparation, rather than weeding, subjects may have reported on their overall use preferences, rather than only considering land preparation.
3. Many subjects perceived the short-handled hoe to be faster than the long-handled hoe, as previously discussed.
4. The subjects are accustomed to lifting their short-handled hoe above horizontal before swinging downward, particularly when the soil is dry and hard. They did the same with the long-handled hoe, even though the PI demonstrated that this is not necessary to get adequate tillage. Learning optimal working methods with new tools may take some time.

5. This high lifting may have contributed to the soft wood handles on three long-handled hoes breaking during the initial trial. Some subjects likely remembered this fact, and even though the hoes were repaired, subjects may have considered the long-handled hoes more negatively because they were afraid the handle would break.

Some subjects did recognize the benefits of the long-handled hoe, but many in the group seemed to place less emphasis on the superior physiological and discomfort outcomes of long-handled hoes when forming their attitudes and actions. Other authors have also emphasized that lack of acceptance of an intervention is more often for socio-cultural than technical reasons, and that all these factors must be considered (FAO/IFAD, 1998; Fathallah et al., 2008). The enabling factors for the long-handled and the intervention hoes in general were similar; both are seen to exhibit a number of benefits, but the above-listed barriers seemed to keep many subjects from fully accepting the long-handled hoe.

As described in the theory of diffusion of innovations (Rogers, 2003), those subjects that preferred the long-handled over the short-handled hoe after two months (19%) are likely the innovators and early adopters in the group. We examined the available variables but found no significant differences between these innovators and early adopters compared to those who preferred the short-handled hoe. The Rogers diffusion of innovations theory could provide a useful framework for further research and promotion of interventions more widely in Africa.

Achieving a truly participative and collaborative research process to develop effective interventions requires strong partnerships and achievement of credibility with the farm workers and their leadership/management (Rogers, 2003; Faucett et al., 2007; Fathallah et al., 2008). Great efforts were made by the research team in this regard, which we feel enabled us to gain honest feedback from the participants, evidenced by many participants telling us they did not like the long-handled hoe, but did like the short-handled hoe. Use of Gambian student interviewers was also beneficial as the students were perceived as independent and non-threatening. The use of male (and female) interviewers was culturally acceptable in this study, as it was suggested by Dr. Kuye and approved by the leadership in the garden. There were no significant associations of the interviewer gender and the outcomes or independent variables in the study.

The roles and relationships of men and women in Gambian culture are important in this study. In studies in other African countries (FAO/IFAD, 1998), disapproval by their husbands of an upright working posture when using a long-handled hoe would cause the woman to not use that hoe. In our study, the men did approve of the use of the long-handled hoes, or had basically no opinion. This is possibly because the garden is in a relatively quiet place where few people pass by, so not as many people will see the subjects' working posture, or because of a more tolerant attitude of the men in this village, but reasons for this could be further explored.

Studies conducted in other countries in Africa have emphasized that men are typically responsible for making tools, but need to be more attentive to the needs and requests of women, particularly in terms of women requesting lighter tools (Kaul & Ali, 1992; FAO/IFAD, 1998; Egharevba & Iweze, 2004). The same was true in our study. The government agricultural machinist (a male) that was contracted to replicate the tools absolutely insisted that the tools should be made of metal heavier than that used in the model hoes that the women picked to test, so they would be stronger and less likely to break. Because the PI had arrived in The Gambia only a few weeks before working with the machinist, she did not feel comfortable further insisting that the tools should be lighter. This could also be explained by the tool manufacturers' desire to ensure that the tool will be strong and not break, as a broken tool could give them a bad reputation.

Other studies have shown that lighter tools reduce energy consumption (Ramana & Ananthakrishnan, 2002; Kaul & Ali, 1992) and the subjects in our study re-iterated many times that they preferred the lighter-weight model tools to the slightly heavier replicated intervention tools. However, later in the follow-up period, some women did say that they had grown accustomed to the heavier tools and realized that there were benefits to them.

This study identifies numerous areas for further research. Studies could be conducted on any of the following: a) differing weights of hoes; b) longer follow-up periods, including the entire land preparation season; c) larger plots for timed trials; d) more sensitization on the use of the long-handled hoe; e) optimal width, shape and curvature of the metal heads for the long and a short handled hoes; f) varying lengths of handles; g) optimal handle materials (stronger wood); and h) having one of each intervention tool available to each subject. More in-depth behavior change studies could also be conducted. A survey could also be conducted to see if the subjects in this current study had more tools of this type made or if women outside the study started to use similar tools. It should be noted that he research team was careful to ensure that the interventions could be locally manufactured at a reasonable cost so that the subjects could also obtain the interventions on their own if desired.

Our study does have limitations. The time of the trials in which the subjects used each hoe was shorter than desired, which was also a concern cited by other researchers in similar studies (Nwuba & Kaul, 1986). There was only a limited amount of land at the garden which still required land preparation, so each subject only had 4 small plots to conduct the trials (5-8 meters^2 each). Sometimes the subjects had to work on land that did not belong to their working group, which they were not happy to do, so it was difficult to make them till a larger area of land. With longer working periods, the true differences between long- and short-handled hoes would likely be more evident as workers might need to take breaks to stretch and recover. Only a limited number of heart rate monitors were available during the study, so not every subject could wear a monitor during every trial. The interviewers were trained to use the heart rate monitors, but some interviewers' recorded heart rates had inconsistencies, so all heart rate data for some interviewers were removed from the dataset. Many actions taken in the study were dictated by cultural norms of The Gambia, which were not always appropriate for the PI to try to overcome, particularly at the beginning of the study. After the PI had gained more acceptance and understanding of the culture, it was easier to adapt to cultural norms. Further, data from only one garden may limit the generalizability of the results. However, the participation rate for the randomly selected subjects (other than the 12 group leaders that were automatically included) in the study was 100%, which improves its generalizability.

Conclusions

The new long-handled hoe reduced the time of land preparation by 22% compared to the traditional hoe. The new short handled hoe increased the time by 20%, compared to traditional hoe. The new long-handled hoe took 34% less time than the new short-handled hoe. The discomfort and injury indicators were consistently better for the new long-handled hoe than both the new short-handled and traditional hoes.

From these analyses, it can be concluded that as compared to traditional methods, the hoe interventions chosen in a participatory method were able to:

a. increase worker productivity (long-handled hoe),
b. decrease work-related musculoskeletal discomfort and injury risk indicators (long-handled hoe), and
c. present indicators of long-term acceptance and increased use among the participants after the initial trials (both interventions, particularly the short-handled hoe).

The information on the barriers and enabling factors that are essential for long-term sustainability of the interventions can be used to help identify related interventions that could be successfully implemented in other settings and in the future. This information will be disseminated to NGOs, United Nations agencies, governments, and others involved in introducing interventions in the horticulture sub-sector worldwide, as some of the information could also be applicable in migrant worker populations in developed countries. Further research on the areas listed in the discussion section should help to improve the intervention's long-term effectiveness to improve the lives of those working in labor-intensive agriculture worldwide.

CHAPTER 4

EVALUATION OF A HAND WATER PUMP TO IMPROVE WORK PRODUCTIVITY, HEALTH, AND SAFETY AMONG WOMEN VEGETABLE FARMERS IN THE GAMBIA

Summary

Background: Women vegetable farmers in The Gambia (West Africa) consider water lifting to be their most time-consuming and painful garden task. This mixed-methods study was undertaken to evaluate a hand water pump, selected in a participatory manner, and to identify indicators of its long-term sustainability.

Methods: Subjects (n=48) engaged in two rounds of timed trials (two months apart), alternating between using a hand water pump and traditional rope and bucket methods to lift a pre-determined volume of water. Average and maximum heart rates were measured and subjects reported their discomfort and safety after each trial. Two months later, individual interviews were conducted on subject perceptions of the water pump, and focus group discussions were held one and three months after the first round of trials.

Results: Use of the water pump increased the mean time required to lift the requisite volume of water by 14% ($p<0.01$), compared to traditional water lifting, however, there was no difference between methods among taller (≥ 1.62 m) subjects ($p=0.49$). The water pump increased average and maximum heart rates by 7% and 6%, respectively (each $p<0.01$), compared to traditional water lifting. However, the discomfort and injury indicators were consistently better for the water pump, including significantly reducing lower back discomfort (OR= 0.15, 95%CI= 0.06-0.34), hip and leg discomfort (OR=0.30, CI= 0.12-0.80), and neck and shoulder discomfort (OR=0.30, CI=0.10-0.89). Two months after the first round of trials, most subjects reported that the water pump was safer (65%), faster (77%), and was preferred (77%).

The qualitative findings indicated that the pumps were safer, caused less discomfort, and were perceived as being more efficient. However, qualitative results also showed that the water pump required too much force to turn, the handle was too high, and that the efficiency of water pumping was low.

Conclusions: Measurements of work efficiency and physical work load indicated that the hand pump did not provide an advantage; however, self-reported indicators for discomfort, safety, and overall preference favored the hand pump over the traditional method. Organizations manufacturing and promoting manual water pumps should comprehensively evaluate their pumps and address the identified work efficiency and usability concerns in developing improved pumps for water lifting.

Introduction

Water is essential to life on every continent, including Africa, where the lifting and movement of water is particularly time- and energy-consuming, due to limited application of technology (FAO, 2004). When clean surface water is not readily available, water must be lifted in large quantities for humans and animals to drink, to cook, clean, and wash with, and to use for the irrigation of plants. Because vegetables are composed of 80-95% water, they require large amounts of water to grow (Sanders, 1997). In fact, inadequate irrigation facilities are the main constraint to increasing vegetable production in countries such as The Gambia (West Africa) (NAWFA, 2007).

In addition to lifting most of the water for household use, women in The Gambia also have the primary responsibility for vegetable gardening, an important source of fresh produce, as well as income for the household (Carney, 1998). Vegetable production in The Gambia is typically carried out during the dry season, thus requiring large volumes of water daily. In our preliminary study (Vanderwal et al., 2009), women vegetable farmers in The Gambia stated that watering was the most time-consuming and painful task in the garden, requiring an estimated five hours to lift and carry approximately 400 liters of water every day of the dry season. This has been confirmed by other researchers (Kuye et al., 2006a, Nag et al., 1980; Seck, 2007). The water is typically lifted from the ground (see Figure 4.1) by multiple (~80/day) repetitions of dropping and lifting a bucket (normally 5- 7 liters) tied to a rope into an open well (Vanderwal et al., 2009), which presents multiple physical risk factors for musculoskeletal discomfort/ disorders (MSDs) and injuries (Fathallah et al., 2008).

Figure 4.1. Subject lifting water with rope and bucket (traditional method)

Numerous types of human-powered water-lifting devices have been introduced in Africa by a range of organizations, with varying degrees of stakeholder involvement in their selection and evaluation. Their efficiency is seldom precisely measured or rigorously investigated, but available information indicates that it is variable (FAO, 2004). Few studies were found that evaluate the health, safety, and long-term acceptability of any method of manual water lifting. Accordingly, we used a community participatory research approach (Vanderwal et al., 2009) in which subjects agreed to test a hand crank "rope and washer" water pump, which is promoted by an international non-governmental organization (NGO) working in The Gambia, but is manufactured and maintained locally.

In addition to evaluating the effectiveness of the water pump among the subject population, this study aimed to identify barriers and enabling factors essential for long-term sustainability of the intervention. The specific hypothesis driving this research was that compared to traditional work methods, interventions chosen in a participatory manner will:

a. increase worker productivity;
b. decrease work- related musculoskeletal discomfort and injury risk indicators; and
c. gain long-term acceptance and increased use among the participants after the initial trials.

This study was designed as a mixed-methods study (Creswell et al., 2003). We used quantitative methods to describe worker productivity, discomfort and injury risk indicators, and some indicators of long-term worker acceptance of the interventions, through timed trials and individual interviews. To compliment these data, qualitative individual interviews, focus groups, and observations were also conducted to identify barriers and enabling factors that are essential for long-term sustainability of the intervention.

Methods

Experimental design

The study used a modified repeated treatment design to gather data, as illustrated in Figure 4.2.

Figure 4.2. Study experimental design

Intervention Selection	Intervention testing (2x- Dec and Feb)									Follow up		
(Nov)	*Group A*	X	O_t	-	O_t	X	O_t	-	O_t	(Jan)	(Feb)	(Mar)
O_{fg} O_{fg}										O_{fg}	O_{ii}	O_{fg}
	Group B	-	O_t	X	O_t	-	O_t	X	O_t			

O_{fg} = Focus group observation (conducted jointly with both groups)
O_i = Individual interview observation
O_t = Observation during trials (monitoring and interviews)
X = Use of intervention method in trials
\- = Use of traditional method in trials
Subjects were randomly assigned into Group A or B for the intervention testing trials.

Study location

This research was conducted in a vegetable garden located 1.2 km east of the village of Gunjur, in the Western Region of The Gambia, in West Africa. The field research occurred between November 2008 and March 2009. A local NGO, the Trust Agency for Rural Development (TARUD), established and oversees the garden. TARUD employs a local garden advisor, who served as the main liaison between the research team and the subjects and the main assistant for the principal investigator (PI) of the study. The PI developed significant connections with the leadership of the garden, which enabled strong commitment among subjects to participate in the study. More detailed information on The Gambia, the garden where the study was conducted, and the overall implementation of this body of research is available in an earlier publication (Vanderwal et al., 2009).

Subjects

A total of 212 women work in the garden, each in her own plot. The women are divided into twelve workgroups, with a leader in each group. In addition to the leader of the group, three other women from each group were randomly selected to take part in the study. The PI and the local project assistants met with these 48 subjects to introduce the study, explain the subject eligibility requirements (aged 18 years or over and currently actively engaged in vegetable farming) and administer informed consent in the local language, as approved by the Government of The Gambia Human Ethics Committee (SCC/EC #1123) and the University of Iowa Institutional Review Board (IRB ID# 200808704). All selected women agreed to participate in the study. All subjects were provided with a small monetary incentive for their participation, which was not made known to the participants until the end of the study when the compensation was distributed.

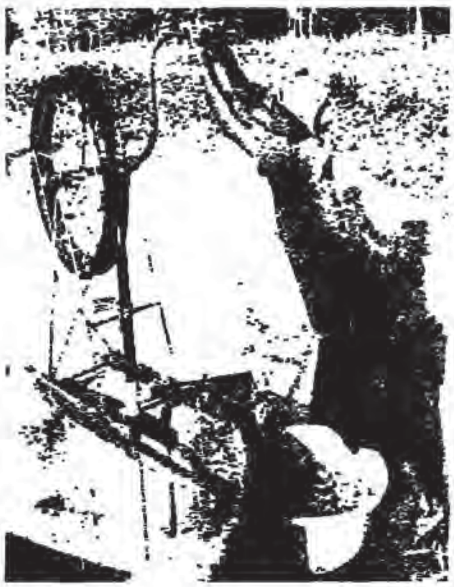
Development of the interventions tested in the study

After the women consented to participate in the study, two participatory focus group discussions were held (in Mandinka, the local language) at the vegetable garden, primarily with the leaders from the twelve garden workgroups, as described by Vanderwal et al. (2009). All focus groups in this study lasted approximately 1-1.5 hours and were conducted at the vegetable garden, digitally recorded, and hand-written notes were also taken by the PI. This participatory approach is similar to methods used in a number of intervention studies, including in labor- intensive agriculture (Meyers et al., 1997; Baron et al., 2001; Earle-Richardson et al., 2005). In the first focus group, participants discussed the methods, timing, safety and work efficiency concerns they have in the various tasks of vegetable gardening, including water lifting. Research team members also observed the subjects during their regular work and conducted targeted interviews with key informants to augment the information gathered in the focus groups.

The research team also presented information on various water pumps which were feasible to be used in the study. Subjects were encouraged to generate ideas of other low-cost methods, or modifications to existing methods, to improve water-lifting. After one week, a second focus group was held where subjects provided feedback on the various intervention options, and agreed to test a hand crank "rope and washer" water pump (see

Figure 4.3). The pump is locally manufactured and maintained through an international NGO operating in The Gambia. Local technicians from the NGO installed two pumps in the garden, at a total cost of approximately 300 USD each.

Figure 4.3. Subject using the hand water pump



The two pumps were installed (on two of the 22 concrete-lined open wells) two weeks before the initial trials occurred. The pumps were then further demonstrated to the subjects and they were encouraged to use the pumps in their routine water lifting tasks. On average, the height from the ground to the pump handles at their lowest position was 0.89 m, and from the ground to the handles at their highest position was 1.63 meters.

Data collection methods

Data collection instruments

All data collection instruments were developed in English with extensive input from the research team in the USA, as well as local research team members, to ensure proper translation and understanding in the local language. In particular, Dr. Rex Kuye, the Gambian member of the research team who had conducted similar research on injuries in farmers in The Gambia (Kuye et al., 2006b), provided a great deal of insight. The officials with the local NGO overseeing the garden also provided input to the data collection instruments and study methodology, based on their experience with the women in the garden. Note also that although the PI of the study could only speak and understand basic Mandinka, a third party (not part of the garden leadership structure or directly assisting with the research) bilingual Gambian accompanied the PI during most of her time in the garden. This person could explain the content of the various discussions and interviews and could check for the interpretation of the questions. This person was typically either a local public health officer or a bilingual driver.

Interviewers

Selected students from an Occupational Health course, taught by the PI, at the School of Public Health at The Gambia College were trained to serve as project assistants and interviewers, at the suggestion of Dr. Kuye and the approval of the leadership of the garden. Interviewers were trained extensively on research principles in occupational health, terminology used in the data collection instruments, and the appropriate translations into the local language. Interviewers practiced administering the questionnaires to other students in the class numerous times, and modifications were made to the data collection forms as necessary based on these practice sessions. Interviewers were also trained to use the heart rate monitors (Reebok Precision Trainer XT Heart Rate Monitor with Chest Strap) and timers used in the study. All interviewers were fluent in the local language of Mandinka, and were familiarized with local expressions used in the village where the research was conducted. Of the 12 interviewers working in the initial trials, three were female, four had worked previously as nurses in similar rural villages, one served as a nurse in the village of Gunjur for four years, one student was originally from Gunjur, and many others were from nearby villages.

Implementation of water-lifting trials

Biographical data were collected from the subjects through individual interviews in the local language. Environmental data (air temperature and humidity) were collected every hour during the trials, using an Oregon Scientific portable weather station.

Two rounds of water-lifting trials were conducted, one in December 2008 and the second in February 2009, as described in Table 4.1. In each round of trials, subjects were randomly assigned to either begin with their traditional water lifting or with the hand pump, and alternated between the two methods in subsequent trials, using each method two times (see study experimental design in Figure 4.2). Some subjects (n=7) that completed the December round of trials were not present in the garden the day of the second round of trials, due to other family commitments. Some subjects (n=2 in December and n= 10 in February) requested to not complete their second trial with the pump (n=7 subjects) or the second trials for both the pump and traditional lifting (n=3 subjects). These subjects reported that they were very tired from the previous timed trials, particularly from the use of the water pump, or were generally not feeling well the day of the trials. On average, the mean height and weight of those subjects that did not complete all 4 trials was the same as that of all the subjects (1.59 meters and 59 kg), although they were slightly older (50-59 years) than the mean for all subjects (40-49 years).

In the December trials, subjects were asked to lift 80 liters of water per trial, while in February, the volume required was increased to 100 liters per trial, for a total of 400 liters in four trials, which is similar to the amount subjects typically lift each day (Vanderwal et al., 2009). Subjects were allowed to use the well closest to their garden plot for traditional lifting and the closest pump for the intervention trial, to allow the subjects to more easily utilize the water lifted in their vegetable plot. The depths of the wells used were measured during each round of trials.

Table 4.1. Key characteristics of water lifting trials

Characteristic	**December round**	**February round**
Number of subjects in trial round	48	41
Number of trials conducted	188	149
Volume of water lifted (liters)	80	100
Depth of wells with pump (meters)	3.9 and 4.7	5.8 and 7.8
Depth of wells used for traditional- range (meters)	3.7- 4.7	5.4- 7.9
Length of time pumps were in garden before testing	2 weeks	10 weeks

Before beginning the trial, subjects were fitted with the chest strap and wrist display of a heart rate monitor. Subjects then lifted the required volume of water, which was measured in December with 4- 20 liter plastic containers. In February, the water lifted in the traditional method was measured using 5- 20 liter plastic containers and the water lifted with the pump was measured with 2- 50 liter plastic containers. This enabled subjects to place both containers near the mouth of the pump, and rotate the water spout from one container to the other, while still pumping. The interviewers recorded the length of time required for the subject to lift the requisite volume of water in each trial, as well as the subject's average and maximum heart rate.

After lifting the required volume of water in each trial, subjects were asked questions from the structured questionnaire regarding their discomfort in each of four body regions (neck/shoulders, arms, lower back, legs) while using that water-lifting method in the just-completed trial. Each subject was also asked if they incurred any injuries or had any near misses in that trial and about their feelings of safety and ease of use. For discomfort in the various body regions, the subjects were asked to point to their level of comfort or discomfort on a 5- point hedonic scale consisting of a series of 5 faces (Peterson, 2000), drawn by one of the Gambian interviewers and approved by Dr. Kuye and the garden leadership. The 5 faces ranged from very uncomfortable (unhappy) to very comfortable (happy).

The interviewers were asked to observe the subjects during each trial for any unusual circumstances that may have occurred during that working phase that would dramatically change the subjects' work productivity, discomfort, or injury risk. The interviewers monitored that the subjects lifted the requisite volume of water in each trial and recorded if the subject had a baby on her back or if she was wearing closed toed shoes or any other protective equipment during the trial. Qualitative feedback from the subjects on the water-lifting methods used was also recorded.

After each round of trials, subjects were encouraged to continue to use the water pump in their routine water lifting and to recall their experiences and perceptions of the pump until the next data collection exercise. The PI also observed the subjects whenever she went to the garden, throughout the entire study.

<u>One- month follow-up focus groups</u>

One month after the initial round of trials, a focus group discussion was held, primarily with the twelve leaders of the garden workgroups participating, although all subjects were welcome to attend. The participants were asked for their perceptions of the water pump, their rationale for these thoughts, how much they have been using the pump and why, any injuries or near misses, and the reaction of others to their use of the water pump. The follow-up focus group discussions were conducted in a similar way to those held to select the interventions used in the study, as described in Vanderwal et al. (2009). Subjects were again encouraged to continue to use the water pump in their routine water lifting and to recall their experiences and perceptions of the pump until the next data collection exercise.

Two- month follow-up individual interviews

Immediately prior to the implementation of the February round of water- lifting trials described above, follow-up individual interviews were conducted with all subjects, using six of the same interviewers that were used in the initial trials. Those subjects not present in the garden on the day of the February round of trials were administered the follow-up individual interviews the following week, so that all women participating in the initial trials also participated in the follow-up individual interviews. Each subject was asked questions with a range of pre-determined answers on how much time they have been using the pump, where their plot is located from the pump, any injuries or near misses, and their thoughts on which water-lifting method was safer, easier, faster, and which they preferred to use. Subjects were also encouraged to provide qualitative feedback on the reasons for their preferences and any suggestions they had to improve the water pumps.

Three- month follow-up focus groups

Three months after the initial trials, a final focus group discussion was held, in the same manner and with the same basic questions as in the one-month follow-up discussion. Eleven subjects were randomly assigned to take part in the discussion group on water lifting. Subjects were also asked for any suggestions they had to improve the pump.

Data analysis

Statistical analysis of quantitative data

Generalized Estimating Equations (GEE) was used as the primary regression analysis procedure (Zeger & Liang, 1988, SAS Institute Inc., 2008). GEE was used to calculate and compare the mean values for each method for the continuous outcomes, including: a) time required for the trial; b) average heart rate; and c) maximum heart rate. Potential confounding factors/ affect modifiers for each outcome were identified using univariate modeling in GEE, and interaction terms were created and tested between those variables significant at the $P < 0.05$ level in univariate analysis. Those independent variables that were significant at the $P < 0.05$ level for at least one continuous outcome were included in the multivariable modeling for all three continuous outcomes.

Unadjusted odds ratios and 95% confidence limits were calculated (using GEE) for each dichotomized outcome (discomfort in various body areas and injury near misses), comparing the water pump to the traditional method. Those independent variables and interaction terms that were significant in univariate modeling at the $P < 0.05$ level for at least one dichotomized outcome and were shown to be covariates in previous studies were used in the multivariable modeling for the dichotomized outcomes. We also used the Chi-Square test and Fisher's exact test to compare the number of near misses and injuries between the two methods used in the trials and during the follow-up period.

Logistic regression analysis was used to identify factors that had a significant association with the outcomes reported in the two-month follow-up individual interviews.

For the GEE analysis, the logit link function was utilized for binomial outcomes, with the identity link function used for the continuous outcome. Subject identification number was used as the clustering factor to enable repeated comparisons of the same subject using either the traditional or intervention method, which was the primary independent variable of interest. GEE analyses were performed using PROC GENMOD in SAS Version 9.2 (SAS Institute Inc., 2009)

Analysis of qualitative data

All the information gathered through the various qualitative data collection methods (focus groups, observation, and individual interviews) was analyzed to identify patterns and common themes, with the primary objective of discovering theory explaining subjects' attitudes and behavior with the different types of tools. This process is based on grounded theory (Glaser & Strauss, 1967) and entails the simultaneous processes of data collection, analysis, and theory construction. All qualitative data were recorded on open-ended forms and focus group discussions were digitally recorded. The PI worked with the local project team and the focus group facilitator to understand the focus group data both during and immediately after the discussions. All opinions expressed by subjects were included in the analysis, with particular attention given to the number of subjects reporting a particular point.

Results

Quantitative findings

Subjects

The main demographic characteristics of the forty-eight Gambian women participating in the study are indicated in Table 4.2.

Most (96%) subjects were of the Mandinka tribe, although all subjects spoke the Mandinka language fluently. The majority of the women (79%) reported that they were right- handed, with 19% reporting that they used both hands equally, and 2% reporting that they were left-handed. Most women (75%) reported that their husband had multiple wives; of these, 50% were the first wife, 42% were the second wife and 6% the 3rd wife of their husband. All subjects reported having malaria at some point in their life, but only 6% (n=3) reported that they were admitted to the health center for their most recent case, with an average stay of 3 days. Only one subject indicated she thought she was pregnant, in her first trimester. Subjects did not have a baby on their back in any of the trials. The subjects were typically barefoot in the trials, or wore light rubber sandals ("flip-flops").

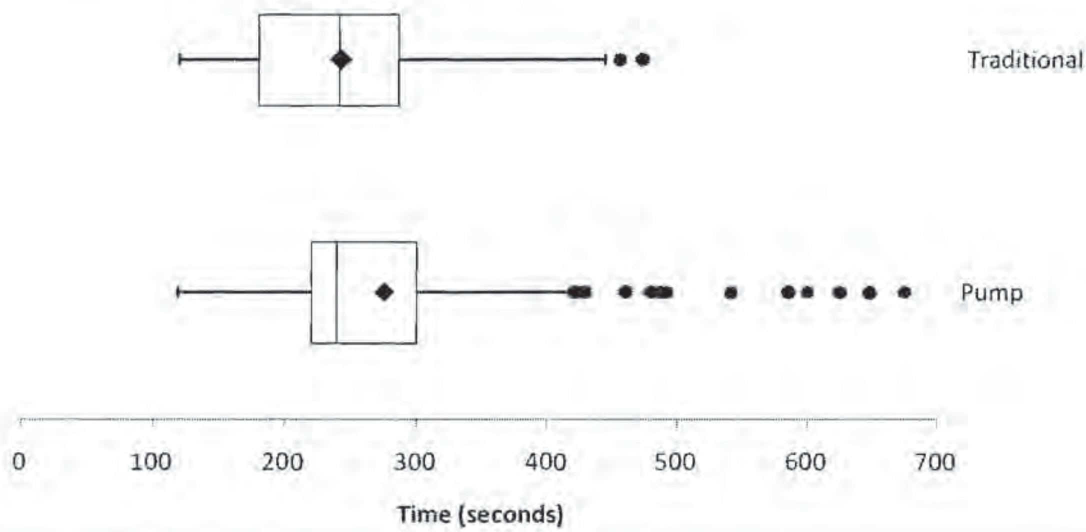
Table 4.2. Characteristics of subjects (n=48)

		Range	
Characteristic	**Mean**	**Min**	**Max**
Height (m)	1.60	1.50	1.73
Weight (kg)	58.7	40	90
10-year age range	40-49 years	18-29 years	80-89 years
Years garden experience (category)	6-10 years	1-5 years	> 20 years

Quantitative outcomes of initial trials

As shown in Figure 4.4 and Table 4.3, the mean time required for the subjects to lift the requisite volume of water with the water pump was 13% longer (95%CI=5.2-20.1%) than with the traditional method. However, as seen in Figure 4.4, the median time values for both methods are the same (240 seconds). A number of trials (n=16) with the water pump were extremely long and were considered statistical outliers, but were observed by the project team to be real values. All except one of these long trials were with subjects that were $\leq$1.62 m tall, as shown in Figure 4.5, but those subjects were in different age categories. Table 4.3 also demonstrates the effect modification of subject height on the time required for each method, as the difference between the methods within shorter subjects (< 1.62 m) was significant ($p < 0.01$), but within taller subjects ($\geq$ 1.62 m), the methods were not significantly different ($p=0.49$). Taller subjects required significantly more time ($p<0.01$) when using the pump than shorter subjects, but when using the traditional method, the difference between height groups was not highly significant ($p=0.07$).

Figure 4.4. Box plot of time required for trials by method



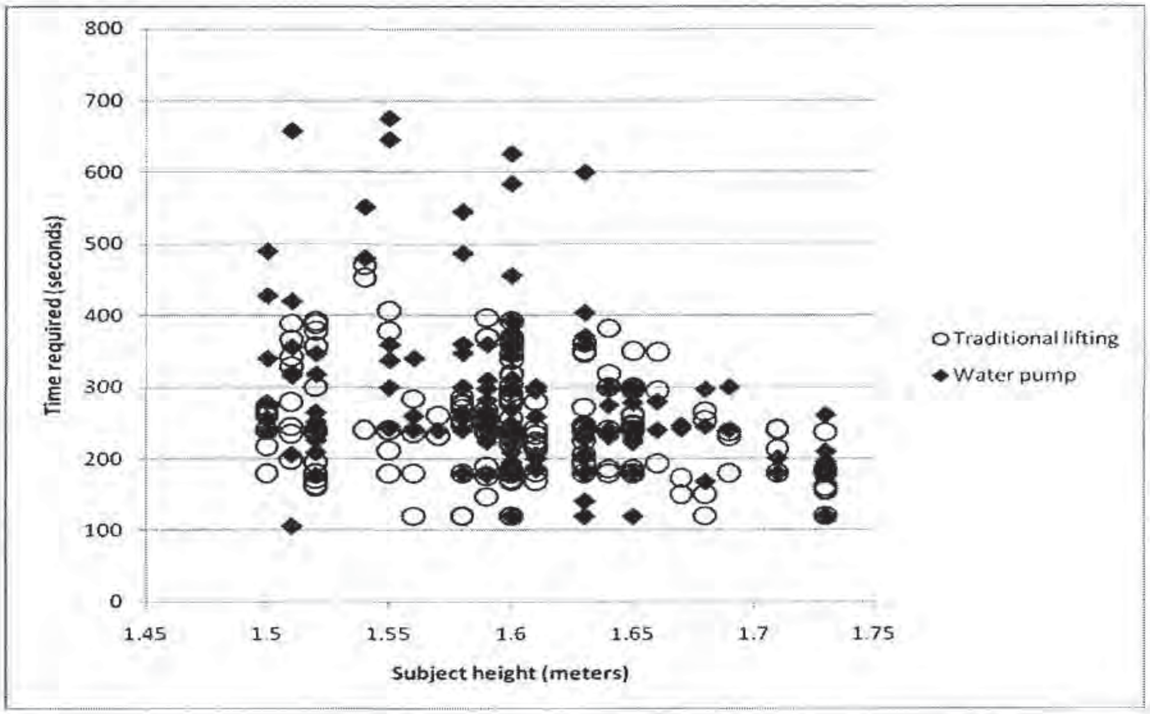
♦ = mean value

Vertical line in center of box= median value

Whiskers outside of the box= minimum and maximum data values that are not statistical outliers.

● = Statistical outliers (data points > 1.5 * the inter-quartile range)

Figure 4.5. Scatter plot of time required for each method, by subject height



Subject average and maximum heart rates were 7% and 6% higher ($p < 0.01$), respectively, when using the water pump than using the traditional method (Table 4.3), with similar results within both height categories. Adjustment for the factors of well depth, month of trial, and subject height and age changed the % differences between methods very little. There were no significant differences in average or maximum heart rates for each method between height categories.

Injuries were reported in two of the 337 water lifting trials, both when using the traditional method. Near misses were reported in 22 of the 173 trials with the traditional method, while only 13 near misses were reported in the 164 trials with the pump (See Table 4.4), although the difference between methods was not significant (Chi-square p value= 0.14).

Table 4.3. Mean values of continuous outcomes by method used and % difference from traditional method

	All subjects			Height < 1.62 m		Height ≥ 1.62 m	
	Mean values		Adjusted†	Mean values		Mean Values	
	Pump (n=164)	Traditional (n= 173)	% difference* (95%CI)	Pump (n=103)	Trad-itional (n=108)	Pump (n=61)	Trad-itional (n=65)
Time required (seconds)	275.6	241.9	+13 (5.2-20.1)	297.7**	250.8	236.2	227.0
Average Heart Rate (bpm)	132.4	124.4	+7 (4.1-8.8)	133.6**	124.9	130.7**	123.8
Maximum Heart Rate (bpm)	144.5	136.1	+6 (3.2-9.4)	144.3**	136.5	144.6**	135.6

bpm= beats per minute

* % difference calculation= ((pump mean value- traditional mean value)/ traditional mean value) * 100%

† Values were adjusted for well depth, month of trial, subject height and age, through a multivariate linear model.

** Value is significantly ($p<0.05$) different than subjects in the same height category using the traditional method.

When conducting univariate analysis on characteristics influencing discomfort in each of the body regions and for injury near misses in these trials, the variables of subject age, height, well depth, and the interaction term of height*method were significant at the $p < 0.05$ level for many outcomes. Subject age, height, and weight have been shown to be important covariates in other studies on risk factors for body discomfort among African farmers (Muruka, 1998; Fabunmi et al., 2005; Naidoo & Haq, 2008), and thus were included in the adjustment of the discomfort and near miss outcomes by water lifting method in Table 4.4. Weight was not included as a potential covariate for discomfort in the neck and shoulders and in the arms and hands as it is typically not a significant risk factor for discomfort in those body regions. The month of the trial, time required for the trial, and average and maximum heart rates were not significant predictors of discomfort in any body region. The consecutive trial number (1, 2, 3 or 4) was also not a significant predictor of any outcome in this study, which indicates that there was no effect of a "learning curve" for the subjects in using a new method for the first time.

As shown in Table 4.4, use of the water pump significantly reduced the odds of subjects reporting discomfort in the lower back. Use of the water pump did appear to reduce the odds of discomfort in all other body regions, as well as injury near misses, but the differences were not significant. After adjustment with the previously indicated factors, the odds of reporting discomfort in the neck and shoulders, lower back, and hips and legs were all significantly less with use of the water pump. All odds ratio estimates did decrease after adjustment, which indicates that some of the covariates did have an effect on reported discomfort and injury near misses, in addition to method. In addition to the interaction term of height*method, which was included in the adjustment factors for all the discomfort outcomes, the interaction terms of height*month of trial, height*well depth, and month of trial*well depth were also significant for hip and leg discomfort. However, because these factors were only significant for one of the discomfort outcomes and to prevent over-fitting of the models, these additional interaction terms were not included in the analyses.

When asked which method they thought was the safest immediately after the completion of each trial, 72% of subjects said the pump was either "definitely" or "probably" safer, 10% said the traditional method was safer, and 17% said both methods were the same. Seventy- two percent (72%) of subjects also said that the pump was easier to use, while 22% said the traditional model is easier, and 6% said both are the same.

Table 4.4. Association of water lifting method with discomfort and injury outcomes

				Unadjusted values			Adjusted* values		
Outcome	Intervention method	N=	% discomfort**	Odds Ratio	Lower CL	Upper CL	Odds Ratio	Lower CL	Upper CL
Neck and shoulder discomfort	Water pump	164	40%	0.56	0.31	1.04	**0.30**	**0.10**	**0.89**
	Traditional	173	54%	-	-	-	-	-	-
Arm and hand discomfort	Water pump	164	37%	0.60	0.33	1.10	0.38	0.12	1.24
	Traditional	173	50%	-	-	-	-	-	-
Lower back discomfort †	Water pump	164	27%	**0.38**	**0.21**	**0.68**	**0.15**	**0.06**	**0.34**
	Traditional	173	49%	-	-	-	-	-	-
Hip and leg discomfort †	Water pump	164	27%	0.61	0.37	1.02	**0.30**	**0.12**	**0.80**
	Traditional	173	38%	-	-	-	-	-	-
Injury near miss‡	Water pump	164	8%	0.59	0.30	1.16	0.56	0.31	1.04
	Traditional	173	13%	-	-	-	-	-	-

* All values were adjusted for subject height and age, well depth and interaction term of height*method.

† In addition, outcomes were also adjusted for weight.

‡ Adjusted for subject height and age only.

** Indicates the % of trials for that method where subjects reported discomfort. For the injury near miss outcome, indicates the % of trials reporting an injury near miss.

Quantitative outcomes of two- month follow-up interviews

Two months after the initial trials, 44% of subjects reported that they had not used the water pump at all since the initial trials, 10 of 48 subjects reported that they had used the water pump 25% of their time, while 11 subjects reported using them 75% or more of their time in water lifting. When given three pre-determined response options, only 10% of subjects reported that a pump is "at the well I normally use", with 19% stating the pump is "next to the well I currently use", and 71% saying the pumps are located "far from the well I normally use."

No injuries were reported with either the water pump or traditional method in the two months after the initial trials. Only three (3) subjects reported an injury near miss when using the traditional method, compared to no near misses reported when using the water pump, but there was no significant difference between the methods (Fisher's exact test p-value= 0.24).

When combining the subject responses of "definitely the pump" and "probably the pump" (shown in Table 4.5), most subjects indicated that they felt the water pump (intervention) was safer (65%), easier (63%), faster (77%), and were preferred (77%).

Table 4.5. Comparison of subject perception of water pump to traditional water lifting methods, two months after the initial trials

	Frequency of persons reporting					
	definitely traditional	**probably traditional**	**both the same**	**probably pump**	**definitely pump**	**TOTAL**
Safer	3 (6%)	5 (10%)	9 (19%)	8 (17%)	23 (48%)	48
Easier	9 (19%)	5 (10%)	4 (8%)	10 (21%)	20 (42%)	48
Faster	5 (10%)	4 (8%)	2 (4%)	14 (29%)	23 (48%)	48
Prefer	7 (15%)	2 (4%)	2 (4%)	9 (19%)	28 (58%)	48
TOTAL	24 (13%)	16 (8%)	17 (9%)	41 (21%)	94 (49%)	192

*The percentages listed immediately after the frequency counts are expressed as the % of the total for that row (listed in the far right column).

The only factor that was significantly associated with any of the follow-up responses in univariate analysis (at $p < 0.05$) was pump location (at or near the well vs. pump far from well), which was predictive ($p < 0.01$) for increasing the amount of time subjects reported using the pump (> 50% vs. < 50% of the time in water lifting). Taller subject height (>1.62 meters; p=0.06) and fewer years of garden experience (<10 years experience; p= 0.10) tended to increase the reported time of using the pump at a $p < 0.10$ level.

Qualitative findings -- barriers and enabling factors essential for long-term sustainability of the intervention

From the qualitative responses in the individual interviews in the initial trials and in the two-month follow-up, the two follow-up focus group discussions, and subject observation, we identified various barriers and enabling factors essential for long-term sustainability of the intervention tested in the study, summarized in Table 4.6 and further explained below. Note that all quotations from subjects are translated into English from the local language of Mandinka.

Table 4.6. Summary of themes in qualitative findings

Barriers	**Enabling Factors**
- Force required to turn the pump	- Improved safety
- Height of pump handle	- Perceived increased productivity
- Unavailability of pumps	- Less discomfort when using
- Lack of familiarity	- Novelty
- Inefficiency of pumping	- Unexpected events less likely
- Pump malfunctioning	- Approval of men and other villagers

Barriers to long-term sustainability of water pump use

Force required to turn the pump

Many subjects reported in the interviews that the pump was "*heavy to crank*" and required "*too much work*" to turn the handle. Numerous (n=2 in December and n= 10 in February) women requested not to complete the final trial with the water pump as they said that at the pump was "*too heavy*". Some women complained of having pains in the chest, side, back, and/or shoulders and respiratory problems when using the pump. One subject also reported in the interviews after the initial trials that "*cranking the heavy bar is painful on my hands*."

Height of pump handle

Through subject observation, it was very apparent that when the pump handles were at their highest point, some of the shorter subjects could barely reach the handle, and all women had to work with their arms over their head when using the pump (see Figure 4.3). One subject noted in the interviews after the trials that "*it is too hard for we little (short) women to use the pump because we can't reach the top*", and another that "*we need to be higher to use the pump.*"

Unavailability of pumps

Numerous subjects reported in interviews and focus groups that there were not enough pumps available in the garden, so they would have to wait to use the pumps or the pumps were located far away from their plots, which would require them to carry the lifted water long distances. One pump was installed near the garden entrance and the other centrally located in the far end of the garden. However, it was evident in the focus groups and interviews that some women were upset that a pump was not placed near their plot. One month after the initial trials, one subject reported in the focus group that "*I am not motivated to work in the garden anymore. Last year I had the best cabbages in the garden, but this year, I am unhappy (because there is no pump near her plot and others have a pump near them).*"

Lack of familiarity

Many subjects indicated in the focus groups and interviews that they have been using the traditional water lifting methods for many years, so using the pump is difficult and uncomfortable until they become more accustomed to it. In the first round of trials, the pumps were brought to the garden only 2 weeks earlier, so many subjects, particularly those whose plots are far from the pumps, had very little experience using them.

Inefficiency of pumping

During the trials, one subject acknowledged that "*it takes time to shift and re-arrange the filled containers (from the pump).*" This was particularly true in the December trials when subjects were to fill 4- 20 liter containers with water. The research team members also noted that due to its design, the pump handle needed to turn a number of times before water would come up through the intake pipe and out through the mouth of the pump. Therefore, every time a subject would stop pumping, the water would fall back down the pipe and when re-starting, additional "dry turns" would be required before the water would come out of the pump again.

Pump malfunctioning

Upon observation, at two different times in the study period, one pump was not working. Both times, it was due to dropped ropes from subjects using the traditional rope and bucket lifting at the same well getting caught up in the intake mechanism of the pump (no fault of the pump). In the second instance, there was a delay in fixing the pump, so it was not working for more than one week. Upon observation, this may have caused the women to think the pump was unreliable or was not working properly and they would decide to use the traditional method instead. The PI noted that a number of times upon her arrival at the garden, women were lifting water using the traditional method at a well where there was a pump. When questioned, the subjects often noted that they "*didn't think the pump was working*", even if it was functioning. Other times, subjects would mention that someone else was using the pump before, so they just continued using the traditional method if they were nearly finished with their watering.

Although not actually a malfunction, the anti-return brake on one of the pumps was observed to be particularly loud when the pump was in use. The brake itself is an important safety feature, but upon observation, the loud noise could be a perceived malfunctioning of the pump, or at least disconcerting to the subjects when the pump is in use.

Enabling factors for long-term sustainability of water pump use

During the two-month follow-up interviews, 75% of the subjects said that they would like to have more pumps in the garden, and many stated that "*every well should have a pump*". One subject stated in the interviews that "*most women like them (pumps) and are happy to have them*" and another that "*we who are near the pumps use them all the time*."

Improved safety

Numerous subjects stated in the interviews and focus groups that the pump was safer and more comfortable, for multiple reasons. The one-month focus group indicated the pump is "*safer as you don't have to lean over the wall (low cement parapet around the well) to lift buckets*". The pumps were also perceived by the three-month focus group to be "*safer for (our) children to help with watering*" as they are less likely to fall into the well. Subject safety was also stated in the interviews following the trials to be improved through reducing the likelihood of the following occurring in the traditional method: a) fingers catching in the rope; b) rope burn on the palms from use of low quality rope; and c) abrasions on knees and toes from hitting the parapet.

During the trials, two subjects incurred injuries when using the traditional water lifting methods. One had an abrasion on her knees from trying to lift the bucket out of the well quickly and hitting the parapet, and the other cut her big thumb as it got caught in the rough rope.

Perceived increased productivity

One month after the initial trials, subjects asserted that "*we feel more productive and profitable (when using the water pumps)*". Multiple subjects said the pumps were faster, easier, and less tedious. In the final focus group discussion, subjects stated that "*the water flows into the bucket faster with the pump*".

Less discomfort when using

Use of the pump was cited in the interviews and focus groups to reduce general body pain and fatigue, including specific mentions of pain in the back, shoulders, neck, arms, chest, and hands/palms. During the initial trials, one subject stated that traditional lifting is "*too tedious a job, my whole body pains*." Another subject said, "*Left to me alone, I will never use the rope and bucket anymore, but the water pump instead so as to rest the shoulders*." Even subjects that prefer to start working with the traditional method recognized in the two-month interviews that the water pump could reduce discomfort, by stating that they "*can use the pump when tired of the traditional method*."

Novelty

When given a list of four possible choices and the opportunity to provide qualitative feedback as to why they preferred the water pump (or traditional method) in the two-month follow-up individual interviews, two subjects selected the option that they preferred the pump as they "*liked to try new things*".

Unexpected events less likely

When using the traditional method, a number of unexpected events appears to be more likely to occur, which can reduce productivity. Upon observation, when dropping the bucket into the well, the end of the rope may also inadvertently fall into the well. When this occurs, subjects typically lower another bucket and rope in the well and try to lift the stranded bucket out of the well. This can be very difficult and time-consuming, and subjects noted in the one-month focus group that if the subject is not able to retrieve their own bucket, they will have to borrow someone else's bucket or will not be able to water their plants that day. When dropping the bucket into a well during the initial trials, one subject's rope got knotted and the subject had to untangle the rope to lower it down to the water level, which was time-consuming.

One subject in the two-month interviews noted that with the traditional method, the buckets (particularly where the handle joins the bucket) may break, thus requiring a replacement bucket. Again, upon observation, if subjects do not have a spare bucket with them (they commonly do not) subjects would have to borrow from someone else or not water their plants that day. They will then have to buy a new bucket, which may be cost prohibitive for some subjects, although it would cost approximately 1USD.

Approval of men and other villagers

The village men did not react to the hand pumps being used in the garden, but subjects in the three-month focus group said "*they can only be happy about the pumps*." Subjects said in three-month focus group that "*most of our neighbors love our hand pumps and want to be a part of the study as well*."

There were no significant relationships found between any of the subjects' qualitative responses and the subject's age, height, weight, garden experience, or any other variable.

Discussion

Honest and comprehensive evaluation of an intervention is essential to affecting the necessary improvements to increase its long-term sustainability and benefits to the user. In this study, the various quantitative and qualitative results provided differing information, all of which was useful in providing suggestions for improvement of the water pump to improve its efficiency and long-term utility.

In the two month follow-up interviews, most subjects said they preferred the water pump over the traditional method, and most (77%) also thought the pump was faster. However, the quantitative results of the trials indicate otherwise.

In several trials with the water pump, the time required was extremely long. The PI did observe a number of these extremely long trials and can verify that the trials did take much longer than many of the other trials, which was also verified by a secondary timing mechanism used. Some of these subjects stopped pumping in the middle of the trial to rest, causing the water to fall out of the intake pipe. Therefore, when the subject started pumping again, she would need to pump a number of times before water would start to come out of the pump again, further extending the time of the trial.

Some subjects did not complete their second trial, primarily with the pump, as they said they were very tired, largely from previous use of the pump. Subjects seemed to "race" in the trials, thus likely tiring more easily than in their typical lifting, which is approximately the same total amount as was required in the trials. Most subjects not finishing the trials were visibly struggling and some complained of chest pain when using the pump during the first trial or in the beginning of their second trial. Although we cannot precisely predict their results, these subjects may have also had very long times for the pump, thus possibly further increasing the mean time for the pump.

The depth of the well from which the water was lifted had a large effect on outcomes of the study, as expected and as evidenced in the univariate analysis with the various outcomes. We tried to have the women use wells of similar depth for the trials, but it was more convenient for them to use the well near their plot so they could easily use the lifted water on their plants. We adjusted for well depth in all the outcomes, and found that it generally had a similar effect on the results for both the traditional method and the pump.

The requisite volume of water was increased from the December to the February round of trials to strengthen the validity of the results. In univariate analysis, the month of the trial did have a significant impact on the time required for the trial and average and maximum heart rate, but it did not significantly affect any of the discomfort or injury variables. Accordingly, the time and heart rate outcomes were adjusted for month of trial, which was found to have a similar effect on the results for both methods.

A number of barriers of the long-term sustainability of the use of the water pump have been identified, which were well-received by the NGO promoting the pump. Upon discussion with the NGO, some suggestions to reduce those barriers were also developed, as follows:

1. A number of women did not complete all their trials, due to their fatigue from using the pump, which a number of subjects said was "*too heavy to turn*." When the idea of testing a rope and washer pump was first presented in the initial focus group discussion, subjects said they thought the pump was "*too heavy*" and didn't want to test it. When the improvements made to the pump (prior to the study) were explained, the subjects eagerly agreed to test the pump. The pump NGO is working to add ball bearings in the pump axle to reduce the difficulty of pumping.
2. On average, when the pumps' handles were at their highest point, they were 1.63 m above the ground. The subjects' median height was 1.60 m, indicating that > 50% of the subjects need to reach above the top of their head to reach the pump handle at its highest point. All subjects with the extremely long times were 1.63 m or shorter (Figure 4.5), demonstrating the reduced productivity, in addition to increased discomfort when working with arms overhead (Violante et al., 2000). Table 4.3 also demonstrates that subject height is clearly an effect modifier of the method of lifting, as there was no significant difference in times between methods in the taller women, but the difference between methods in the shorter women was highly significant. This barrier could also directly affect the previously mentioned barrier, as the subjects that are too short to use the pump comfortably would be more likely to feel the pump is hard to turn. The pump NGO is planning to reduce the radius of the pump handle and make a permanent

raised concrete platform where the women can stand to use the pump, thus taking into consideration the body size and strength of the female users in its design, which is essential for its long-term sustainability (Kaul & Ali, 1992; FAO/IFAD, 1998; Egharevba & Iweze, 2004).

3. Only two pumps were installed in this study, which the qualitative results strongly indicate was a barrier to use of the pumps. However, the PI noted various times on arrival in the garden that women were using the traditional method at the same well as there was a functioning and available pump, indicating that there are also other important barriers to their long-term use. The subjects could pool their money to purchase more, or could request funds from another project to install more pumps.
4. Some subjects prefer to continue in the method they are accustomed to, regardless of the utility of the method (Rogers, 2003). In the qualitative results, increasing subject age seems to decrease subject acceptance of the pump. The only age-related variable that had a statistical association with any of the quantitative follow-up responses was years of garden experience (<10 years, $p=0.10$) with reported use of the pump. Increasing the number of pumps and the amount of time the subjects have to become familiar with them will help to address this barrier.
5. The pump NGO is exploring other pump designs that would improve the efficiency of the pump by holding the water in the intake pipe for the next use, while not increasing friction in pumping. Another improvement could be to have a large reservoir of water (~100 liters or more) at the outlet of the pump, so that the subjects could pump water continuously to fill the reservoir, without the need to stop to re-position the receiving buckets. This could be particularly beneficial if one person could crank the pump while others fill buckets and carry the water

away. The water could eventually also be channeled from the reservoir directly to the plots.

6. Although it was not the fault of the pump that it did not work for some periods of time in this study, the pumps could malfunction in other ways as time passes. The pump technicians should become more skilled at fixing the pump over time, which should reduce the amount of time a pump is not working. The pump NGO is also planning to reduce the noise of the anti-return brake of the pump.

Although use of the pump required more time and effort in our study than the traditional method, the trial results indicate that the pump improved comfort and safety. The two-month follow-up data also indicates that most of the women (77%) prefer the pump over the traditional water lifting method, which is reinforced by the <u>enabling factors</u> for long-term sustainability that were identified through the qualitative results, as follows:

1. The quantitative and qualitative results strongly indicate that the pump is safer. Use of the pump reduced the likelihood of near misses and injuries, and subjects also report that they felt the pump was safer and easier, both during the trials and in the follow-up interviews. The qualitative results also emphasize the improved safety of the pump, which the members of the research team agree with, based on first-hand experience of using both methods.
2. Although the timed trials seem to indicate otherwise, 77% of subjects in the two-month follow-up interviews felt that the pump was faster than the traditional method. This is possibly because once the water actually starts coming out of the pump, it does continuously flow relatively fast, which may cause the subjects to perceive that the pump is faster. This could be further explored in future studies using longer time periods, particularly after modifications to the pump have been made.

3. Some subjects indicated that using the pump caused less discomfort, while other subjects complained of having pains in multiple body parts while using the pump, particularly when lifting larger volumes of water in the February trials. The factors determining when subjects experience more or less pain in using the pump could also be further explored, particularly after the pump modifications are made.
4. Some subjects seem to like the idea of receiving and having something new in the garden, and may say positive things about the new item mainly so that they can receive more new interventions and to try to please the research team, regardless of the utility of the item.
5. Although the possible unexpected events when using the traditional method do not occur often, the subjects who do experience them will be more likely to strongly support the use of the pump.
6. In African society, men's approval of the women's working tools and methods is very important. The village men had no objections to the use of the hand pump, but studies have shown that male disapproval of women's use of water pumps such as the leg-operated treadle pump (considered an indecent posture) will cause the woman not to use the available technology (Kaul, 1993) .

Another important factor of the sustainability of the pump, which was not explicitly studied in this project, is the cost and ease of installation and maintenance. The pump tested in this study was selected by the NGO promoting it because it was said to be low-cost, simple to operate and locally maintain, durable, and efficient. However, little documentation was found on the systematic evaluation of any manual water pumps in Africa (FAO, 2004), particularly of their effects on health and safety. Foot- operated treadle pumps are used more commonly than hand-crank pumps for irrigation projects throughout Africa as the stronger leg muscles power the treadle pump (FAO, 2004). The treadle pump was mentioned to the subjects as a possible intervention during the initial focus group, but the subjects said it was "*too hard*" to pump and did not want to test it (Vanderwal et al., 2009).

This study identifies numerous areas for further research, including the following:

- After the indicated improvements are made to the pump, similar trials could be conducted to evaluate the improvements;
- Two different pump models could be tested, such as a treadle pump or a different type of hand pump, along with the improved rope and washer pump;
- Evaluation of the number of "dry" turns required before water will flow again after breaks of different lengths (5, 10, 15 seconds, etc);
- Increasing the volume of water required for lifting;
- Longer follow-up periods to monitor subject use of the pump over time;
- Monitor the same outcomes in a smaller number of subjects using one method exclusively for a longer length of time (for example, one week), then switching to another method the next week; and
- Increasing the number of pumps available in the garden so more women have access to them.

There were a number of challenges in implementing this study. The research team noted that the subjects did not always fill the containers completely, but it can be assumed that each subject would fill the containers in the two methods to the same level. Because subjects were more accustomed to the traditional method, it seemed to be easier for them to "race" in the timed trials with the traditional method than with the pump. This limitation could be addressed by increasing the amount of water required for lifting. However, not all of the women completed the trials due to fatigue under these study conditions, which could be worse if the volume required was increased.

Although numerous steps were taken to build a strong partnership with the subjects (Vanderwal et al., 2009), so that they would report honestly (Faucett et al., 2007), it appears that to some degree, subjects may have reported they liked the pump to please the study team and to keep receiving new things. This may be addressed by having subjects evaluate two different pump types and the traditional method.

The interviewers were trained to use the heart rate monitors, but some interviewers' recorded heart rates had several inconsistencies, so all heart rate data for some interviewers were removed from the dataset. Further, data from only one garden may limit the generalizability of the results. However, the participation rate for the randomly selected subjects (other than the 12 group leaders that were automatically included) in the study was 100%, which improves its generalizability.

Conclusions

Use of the water pump increased the mean time required to lift the requisite volume of water by 14%, compared to traditional water lifting, which was partially caused by a number of extremely long trials when shorter women were using the water pump . The water pump increased average and maximum heart rates by 6% each compared to traditional water lifting. However, the discomfort and injury indicators were consistently better for the water pump than for the traditional method, and a majority (77%) of subjects reported after two months that they preferred the water pump.

From these analyses, it can be concluded that as compared to the traditional methods, the water pump, an intervention selected in a participatory method, was able to:

a. decrease work-related musculoskeletal discomfort and injury risk indicators, and
b. present indicators of long-term acceptance and increased use among the participants after the initial trials.

Based on the results of this study, a number of improvements are already being made to the pump, which should enable it to also increase measured worker productivity. Modified study conditions, including a longer period of study, may also demonstrate that the pump helps to increase worker productivity under those conditions.

The information on the barriers and enabling factors essential for long-term sustainability of the intervention could be used by other pump manufacturers, distributors, and promoters to provide improved pumps in developing countries, particularly for women vegetable farmers in Africa. This information will be disseminated to NGOs, United Nations agencies, governments, and others involved in introducing water lifting devices and irrigation technology throughout Africa.

CHAPTER 5

CONCLUSIONS

The research presented in this dissertation demonstrates that interventions selected in a participatory manner, among women vegetable farmers in the Gambia, can accomplish the following:

a. increase worker productivity (long-handled hoe);
b. decrease work-related musculoskeletal discomfort and injury risk indicators (long- handled hoe and water pump); and
c. present indicators of long-term acceptance and increased use among subjects after the initial trials (hoe interventions, particularly the short-handled hoe; water pump).

The interventions selected and evaluated in this dissertation can be utilized by women farmers in other areas of the Gambia, and throughout Africa to help to reduce the drudgery, as well as the discomfort and injury risk associated with labor-intensive agriculture. More importantly, the barriers and enabling factors for the long-term sustainability of such interventions can be utilized to improve existing interventions and in developing future interventions in this area. This information for the water pump has already been presented and discussed with the NGO promoting it, who immediately began making plans to improve the pump. These improvements should enable it to also increase measured work productivity.

The lessons learned in implementing the community participatory approach utilized in this study can be useful to others establishing such an approach, particularly in countries with similar cultures to the Gambia. This approach can help the beneficiaries of an intervention to identify their needs and to develop culturally-appropriate means to address those needs. Further, the use of the mixed-methods approach, combining qualitative and quantitative techniques, was very useful in providing objective data which could be further explained by qualitative findings. This approach can be utilized to more rigorously evaluate other interventions intended to improve aspects of labor-intensive agriculture.

All the information gained in this research will be disseminated to NGOs, United Nations agencies, governments, water pump and tool suppliers, and others involved in introducing interventions in the horticulture sub-sector in both developed and developing countries, as some of the information could also be applicable in migrant worker populations in developed countries. By sharing this information with a broad range of groups, more farm workers, particularly those in labor-intensive agriculture, should have the possibility of reducing the drudgery, discomfort, and injury risk involved in their work.

Farming is a large and essential occupation worldwide, particularly in developing countries such as the Gambia, where more than 2/3 of the population is engaged in agricultural production (ILO, 2000). Women in the Gambia are estimated to be responsible for nearly 2/3 of the agricultural work in the country (Akinoboade, 1994). Farming has also long been cited as one of the three most hazardous occupations, in both developed and developing countries (ILO, 2000). Therefore, an extremely large number of people, particularly in developing countries, are exposed to numerous occupational health risks in their routine farming operations.

Accordingly, this research can positively impact large numbers of women, particularly in Africa. Improving the productivity, health and safety of women farmers not only benefits the workers themselves, but also allows them to produce more food, which increases food security for the entire nation. Women also carry out the majority of household tasks in developing countries, so any improvements to their work in vegetable gardens will also favorably impact their entire household.

In the first phase of this research (Chapter 2), interventions were selected for three vegetable garden tasks. The evaluation of the interventions for land preparation and water lifting are presented in this dissertation in Chapters 3 and 4, respectively. An intervention (a flat plastic tray) was also selected and evaluated for transporting vegetables, but is not presented in this dissertation, as this intervention did not lend itself to the same type of quantitative evaluation as the land preparation and water lifting interventions. The tray was qualitatively evaluated in the same manner as the other interventions, and was shown to be highly accepted by the research subjects. In fact, it seemed to be the most successful of any of the interventions, and may be reported on more extensively in future publications.

These studies identify numerous areas for future research, including the following:

- Expanding the research to other vegetable gardens, utilizing methodology and information obtained in this current research;
- Longer follow-up periods for evaluation, including appraising the long-term sustainability of the interventions implemented in this research;
- Increasing the amount of work to be accomplished in the trials, to better evaluate the differences between the methods;
- Monitoring the same outcomes in a smaller number of subjects using one method exclusively for a longer length of time (for example, one week), then switching to another method the next week;
- Further study on the adoption of innovations- including evaluating the factors affecting this adoption;
- Conducting trials with hoes of different weights and designs, as well as at least two different designs of manual pumps; and
- Testing the improved water pumps after the suggested changes have been affected.

Further research on the areas listed above should help to improve the interventions' long-term effectiveness to improve the lives of the many people working in labor-intensive agriculture worldwide.

APPENDIX A

BASIC BIO-DATA QUESTIONNAIRE

Subject ID__________________________

Interventions to Improve the Health, Safety, and Productivity of Vegetable Farmers

Basic Bio-data Questionnaire (independent variables)

Interview Script

Before the interview, please enter the following information:

Date of Interview: __ __/__ __/__ __ __ __

Time of Interview: ____ : __ __ (24 hour clock)

Interviewer Name: ______________________

Interviewer:

"Thank you for taking your time for this interview. I would like to ask you some basic questions about you and your background. If at any time during this or any of the interviews you will go through today, you would like to stop, please feel free to tell me. If you do not want to answer a specific question let me know and we will move on to the next one."

"Do you have any questions before we begin?"

- If yes: Answer any questions until the subject is satisfied she completely understands the interview procedure.
- If no: Begin the interview.

"Let's begin."

1. **Subject height** (measured with a tape measure in cm) _________________

2. **Subject weight** (measured with a balance in kg) _________________

3. **Which of the following groups *best* describes your tribe?** *(circle one)*
Mandinka, Wolof, Fula, Jola, Karoninka, Manjago, refused, dont know,
other: _________________

4. **What is your age (in years)?** *(circle one)* Are you 18-29, 30-39, 40-49, 50-59,
60-69, 70-79, 80-89, refused, don't know

5. **Which hand do you use more for your daily tasks?** *(circle one)*
Right, left, both, prefer not to answer, dont know

6. **How many years have you worked in a vegetable garden?** *(circle one)*
Less than 1, 1-5, 6-10, 10-20, more than 20, refused, dont know

7. **Do you think that you are pregnant?**
Yes No refused don't know

7a. **If so, for how many months have you been pregnant?** *(circle one)*
1-3, 4-6, 7-9, refused, dont know

8. **Are you the only wife of your husband?**
Yes No refused don't know

8a. If "no", are you the 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, other, refused, dont know
(circle one)

9. **When was your last case of malaria?** *(circle one)*
Less than 1 month ago, 1-3 months ago, 3-6 months ago, 6-12 months ago
More than 12 months ago, never had malaria
Note to interviewers: if the women tell you the case was during a particular event (ie Koriteh), please calculate the length of time that has passed since that event.

10. Were you admitted to the Health Center for that case?
Yes No refused don't know

10a. If yes, for how many days were you admitted? *(circle one)*
1 day, 2 days, 3 days, more than 3 days

"Thank you for your time in completing this interview. We will be using the results from this interview when we analyze the rest of the information from this study.

Do you have any questions concerning this study? Later on, if you have any questions please feel free to contact Londa Vanderwal (Miriama Demba), study investigator in the Gambia, in person or by telephone at 974 8892.

Thanks again for your time today."

APPENDIX B

LAND PREPARATION TRIALS

OUTCOME RECORD

Subject ID____________________

Outcome record for HOEING/ LAND PREPARATION

Method used: Traditional hoe, long-handled hoe, short-handled hoe *(circle one)*

Repetition of the trial: 1 2 3 4 *(circle one)*

Interviewer Name: ____________________

Starting time of hoeing _____ (24 hr clock) Ending time of hoeing ______ (24 hour clock)

Time on heart rate monitor___________

Record heart rate:
Average:_________ (beats per minute) Maximum: __________(beats per min)

Ask subject the following questions:

1. What level of discomfort did you experience in your neck and/or shoulders while using this method?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ __________ O __________ O __________ O __________ ☺
Middle face

refused, don't know

2. What level of discomfort did you experience in your elbows, forearms, wrists, hands, and/or fingers while using this method?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ __________ O __________ O __________ O __________ ☺
Middle face

refused, don't know

3. What level of discomfort did you experience in your lower back while using this method?

☹ __________ O __________ O __________ O __________ ☺
Middle face

refused, don't know

4. What level of discomfort did you experience in your hips, knees, ankles, and/or feet while using this method?

☹ __________ O __________ O __________ O __________ ☺
Middle face

refused, don't know

5. Did you incur any unintentional injuries, such as a cut, puncture, burn, bruise, etc, when using this method?

Yes No refused don't know

6. While using this method, did you ever feel that you were very close to having an injury, but one did not actually occur?

Yes No refused don't know

Ask questions 7 and 8 only after use of either of the new methods (long or short- handled hoe).
7. Compared to the traditional method, how did you feel using this intervention method?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹	O	O	O	☺
Much less safe	less safe	the same	safer	much safer

refused, don't know

8. Compared to the traditional method, did this intervention method make your work easier or harder?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹	O	O	O	☺
Much harder	harder	the same	easier	much easier

refused, don't know

The interviewer should also note the following points before and while the woman is working during this testing phase:

1. **Percentage of time with baby on back during the task: (circle one)**

   0%, 1-24%, 25-49%, 50-74%, 75-99%, 100%

2. **Personal Protective Equipment used during this testing phase: (circle all applicable)**
   None, closed toed shoes, boots, gloves, cloth wrapped around hand,
   Other (please list): ______________________

3. **Please note any unusual circumstances that may have occurred during this working phase** that would dramatically change the subject's productivity or heart rate

4. **Depth of soil tilled/ quality of tillage/ other comments of the women:**
   (measure the depth of soil tilled and/or write comments on the quality of work accomplished in this phase; write any comments the woman may have on the tool used)

APPENDIX C

WATER LIFTING TRIALS- DECEMBER

OUTCOME RECORD

Subject ID#______________________

Outcome record for WATER LIFTING

Method used: Traditional lifting, water pump *(circle one)*

Repetition of the trial: 1 2 3 4 *(circle one)*

Interviewer Name: ____________________

Starting time of lifting ______ (24 hr clock) Ending time of lifting ______ (24 hour clock)

Record heart rate:
Average:______(beats per minute) Maximum: _______(bpm) watch time elapsed______

Ask subject the following questions:

1. What level of discomfort did you experience in your neck and/or shoulders while using this method?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ ____________ O ____________ O ____________ O __________ ☺
Middle face

refused, don't know

2. What level of discomfort did you experience in your elbows, forearms, wrists, hands, and/or fingers while using this method?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ ____________ O ____________ O ____________ O __________ ☺
Middle face

refused, don't know

3. What level of discomfort did you experience in your lower back while using this method?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ ____________ O ____________ O ____________ O __________ ☺
Middle face

refused, don't know

4. What level of discomfort did you experience in your hips, knees, ankles, and/or feet while using this method?
Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ ____________ O ____________ O ____________ O __________ ☺
Middle face

refused, don't know

5. Did you incur any unintentional injuries, such as a cut, puncture, burn, bruise, etc, when using this method?

Yes No refused don't know

6. While using this method, did you ever feel that you were very close to having an injury, but one did not actually occur?

Yes No refused don't know

Ask questions 7 and 8 only after use of either of the new methods (new rope and bucket or pump).
7. Compared to the traditional method, how did you feel using this intervention method?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ ________ O ________ O ________ O ________ ☺
Much less safe less safe the same safer much safer

refused, don't know

8. Compared to the traditional method, did this intervention method make your work easier or harder?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ ________ O ________ O ________ O ________ ☺
Much harder harder the same easier much easier

refused, don't know

The interviewer should also note the following points before and while the woman is working during this testing phase:

1. **Percentage of time with baby on back during the task: (circle one)**
   0%, 1-24%, 25-49%, 50-74%, 75-99%, 100%
2. **Personal Protective Equipment used during this testing phase: (circle all applicable)**
   None, closed toed shoes, boots, gloves, cloth wrapped around hand,
   Other (please list): ________________
3. **Please note any unusual circumstances that may have occurred during this working phase** that would dramatically change the subject's productivity or heart rate

APPENDIX D

WATER LIFTING TRIALS- FEBRUARY

OUTCOME RECORD

Date_______________ **Subject ID**_________________________

Outcome record for **<u>WATER LIFTING</u>**

Method used: Traditional lifting, water pump *(circle one)*

Repetition of the trial: 1 2 3 4 *(circle one)*

Interviewer Name: ____________________

Time on stop watch to accomplish task (min and seconds) ______________

Record heart rate:
Average:____(beats per minute) Maximum: _____(bpm) Time on HR timer_______

Ask subject the following questions:

1. What level of discomfort did you experience in your <u>neck and/or shoulders</u> while using this method?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ ____________ O ___________ O ____________ O __________ ☺
Middle face
refused, don't know

2. What level of discomfort did you experience in your elbows, forearms, wrists, hands, and/or fingers while using this method?

Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ ____________ O ___________ O ____________ O __________ ☺
Middle face
refused, don't know

3. What level of discomfort did you experience in your lower back while using this method?
Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ ____________ O ___________ O ____________ O __________ ☺
Middle face
refused, don't know

4. What level of discomfort did you experience in your hips, knees, ankles, and/or feet while using this method?
Show the subject the smiley face scale sheet and ask them to point where they feel on the scale

☹ ____________ O ___________ O ____________ O __________ ☺
Middle face
refused, don't know

5. Did you incur any unintentional injuries, such as a cut, puncture, burn, bruise, etc, when using this method?

Yes No refused don't know

6. While using this method, did you ever feel that you were very close to having an injury, but one did not actually occur?

Yes No refused don't know

7. Based on this trial, which method of water lifting do you feel is the safest to use?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the pump	definitely the pump

8. Based on this trial, which method of water lifting makes your work easier?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the pump	definitely the pump

The interviewer should also note the following points before and while the woman is working during this testing phase:

1. **Percentage of time with baby on back during the task: (circle one)**

   0%, 1-24%, 25-49%, 50-74%, 75-99%, 100%

2. **Personal Protective Equipment used during this testing phase: (circle all applicable)**
   None, closed toed shoes, boots, gloves, cloth wrapped around hand,
   Other (please list): ____________________

3. **Please note any unusual circumstances that may have occurred during this working phase** that would dramatically change the subject's productivity or heart rate

APPENDIX E

LAND PREPARATION

TWO-MONTH FOLLOW-UP INTERVIEW FORM

Date______ **Subject ID____________** **Interviewer Name__________**

Opening questionnaire on hoe use/ land preparation since previous trial

1. Since the new hoes have been in the garden (before Tabaski), approximately what percentage of your time <u>in land preparation</u> do you use the <u>long</u>-handled hoe? *(circle one)*
0% 25% 50% 75% 100% refused don't know

2. Since the new hoes have been in the garden (before Tabaski), approximately what % of your time in land preparation do you use the new short-handled hoe? (circle one)
0% 25% 50% 75% 100% refused don't know

3. Has the <u>long</u>-handled hoe been available to you to use? (circle one)
I can use it any time I like I have to ask to use, but receive it right away
I have to ask to use and then wait until later in the day to use
I have to wait many days to be able to use the hoe

4. Has the <u>short</u> -handled hoe been available to you to use? (circle one)
I can use it any time I like I have to ask to use, but receive it right away
I have to ask to use and then wait until later in the day to use
I have to wait many days to be able to use the hoe

5. Have you incurred any unintentional injuries, such as a cut, puncture, burn, bruise, etc, when using the long-handled hoe since it was available?
☐ Yes ☐ No ☐ refused ☐don't know

6. Have you incurred any unintentional injuries, such as a cut, puncture, burn, bruise, etc, when using the short-handled hoe since it was available?
☐ Yes ☐ No ☐ refused ☐don't know

7. Have you incurred any unintentional injuries, such as a cut, puncture, burn, bruise, etc, when using the traditional hoe for land preparation (since the new hoes were available)?
☐ Yes ☐ No ☐ refused ☐don't know

8. While using the long-handled hoe, have you ever felt that you were very close to having an injury, but one did not actually occur?
☐ Yes ☐ No ☐ refused ☐don't know

9. While using the short-handled hoe, have you ever felt that you were very close to having an injury, but one did not actually occur?
☐ Yes ☐ No ☐ refused ☐don't know

10. While using the traditional hoe for land preparation (since the new hoes were available), have you ever felt that you were very close to having an injury, but one did not actually occur?
☐ Yes ☐ No ☐ refused ☐don't know

11. Which method of land preparation do you feel is the safest to use?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the new hoes	definitely the new hoes

12. Which method of land preparation makes your work easier?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the new hoes	definitely the new hoes

13. Which method of land preparation do you feel is faster?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the new hoes	definitely the new hoes

14. Which land preparation method do you normally prefer using?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the new hoes	definitely the new hoes

15. Why do you prefer that method? (Circle all those that apply)

a) The new hoes are difficult to use b) I am used to using the traditional method
c) There are usually many people waiting to use the new hoes and I don't want to wait
d) I like to try new things e) Other. *(Please list)*

16. Between the short and long handled hoe, which do you feel is the safest to use?

O	O	O	O	O
Definitely Short- handled	probably short- handled	both feel the same	probably long-handled	definitely long-handled

17. Between the short and long handled hoe, which makes your work easier?

O	O	O	O	O
Definitely Short- handled	probably short- handled	both feel the same	probably long-handled	definitely long-handled

18. Between the short and long handled hoe, which do you feel is faster?

O	O	O	O	O
Definitely Short- handled	probably short- handled	both feel the same	probably long-handled	definitely long-handled

19. Between the short and long handled hoe, which would you normally prefer to use?

O	O	O	O	O
Definitely Short- handled	probably short- handled	both feel the same	probably long-handled	definitely long-handled

20. Why do you prefer that method? (Circle all those that apply)

a) I am used to using a short handled hoe
b) people laugh when I use the long-handled hoe
c) There are usually many people waiting to use the short-handled hoes and I don't want to wait
d) I like to try new things
e) Other. *(Please list)*

21. Do you have any suggestions for future improvements to the hoes (both the long and short) or to your land preparation methods?

APPENDIX F

WATER LIFTING

TWO-MONTH FOLLOW-UP INTERVIEW FORM

Date_________ **Subject ID**______________ **Interviewer Name**__________

Opening questionnaire on water pump use since previous trial

1. Since the water pumps have been in the garden (before Tabaski), approximately what percentage of your time watering do you use the <u>water pump</u>? *(circle one)*
0% 25% 50% 75% 100% refused don't know

2. Where are the water pumps located from your plot? (circle one)
At the well that I normally use next to the well I normally use far from the well I normally use

3. Have you incurred any unintentional injuries, such as a cut, puncture, burn, bruise, etc, when using the water pumps since they were installed?
☐ Yes ☐ No ☐ refused ☐don't know

4. Have you incurred any unintentional injuries, such as a cut, puncture, burn, bruise, etc, when using the traditional rope and bucket lifting (since the pumps were installed)?
☐ Yes ☐ No ☐ refused ☐don't know

5. While using a water pump, have you ever felt that you were very close to having an injury, but one did not actually occur?
☐ Yes ☐ No ☐ refused ☐don't know

6. While using the traditional rope and bucket lifting (since the pumps were installed), have you ever felt that you were very close to having an injury, but one did not actually occur?
☐ Yes ☐ No ☐ refused ☐don't know

7. Which method of water lifting do you feel is the safest to use?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the pump	definitely the pump

8. Which method of water lifting makes your work easier?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the pump	definitely the pump

9. Which method of water lifting do you feel is faster?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the pump	definitely the pump

10. Which water lifting method do you normally prefer using when you come to the garden?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the pump	definitely the pump

11. Why do you prefer that method? (Circle all those that apply)
a) The pump is too far from my plot b) I am used to using the traditional method
c) There are usually many people waiting to use the pump and I don't want to wait
d) I like to try new things e) Other. *(Please list)*

12. Do you have any suggestions for future improvements to the water pumps or to how you lift water?

APPENDIX G

VEGETABLE TRANSPORT

TWO-MONTH FOLLOW-UP INTERVIEW FORM

Date____ Subject ID_________________ Interviewer Name__________

Opening questionnaire on vegetable transport since previous trial

1. Since the plastic trays have been available (before Tabaski), approximately what percentage of your time transporting vegetables do you use the flat plastic trays? *(circle one)*
0% 25% 50% 75% 100% refused don't know

2. Have the plastic trays been available to you to use? (circle one)
I can use them any time I like I have to ask to use, but receive it right away
I have to ask to use and then wait until later in the day to use
I have to wait many days to be able to use the plastic tray

3. Have you incurred any unintentional injuries, such as a cut, puncture, burn, bruise, etc, when using the plastic trays to transport vegetables?
☐ Yes ☐ No ☐ refused ☐ don't know

4. Have you incurred any unintentional injuries, such as a cut, puncture, burn, bruise, etc, when using the traditional vegetable carrying method (since plastic trays were available)?
☐ Yes ☐ No ☐ refused ☐ don't know

5. While using a plastic tray to transport vegetables, have you ever felt that you were very close to having an injury, but one did not actually occur?
☐ Yes ☐ No ☐ refused ☐ don't know

6. While using the traditional vegetable transporting methods (since the plastic trays were available), have you ever felt that you were very close to having an injury, but one did not actually occur?
☐ Yes ☐ No ☐ refused ☐ don't know

7. Which method of transporting vegetables do you feel is the safest to use?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the crates	definitely the crates

8. Which method of transporting vegetables gives the highest quality/ integrity of the produce after transporting?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the crates	definitely the crates

9. Which method of transporting vegetables do you feel is faster?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the crates	definitely the crates

10. Which method of transporting vegetables do you normally prefer to use?

O	O	O	O	O
Definitely Traditional	probably traditional	both feel the same	probably the crates	definitely the crates

11. Why do you prefer that method? (Circle all those apply)
a) The crates are difficult to use b) I am used to using the traditional method
c) The crates are not available to me d) I like to try new things
e) Other. *(Please list)*

12. Do you have any suggestions for future improvements to the plastic vegetable trays or to how you transport vegetables?

REFERENCES

Akinoboade O. The implementation of the Gambian Agricultural Development Policy: lessons from impact. African Development Review. 1994;6(2):40-69.

Aubel J, Samba-Ndure K. Lessons on sustainability for community health projects. World Health Forum. 1996;17(1):52-7.

Badiger C, Hasalkar S, Hosamani S. Drudgery reduction of farm women through technology intervention. Karnataka Journal of Agricultural Sciences. 2006;19(1):182-3.

Baron S, Estill C, Steege A, Lalich N. Simple solutions: ergonomics for farmworkers. DHHS (NIOSH) Publication No. 2001-111. Cincinnati: NIOSH; 2001.

Carney J. Women's land rights in Gambian irrigated rice schemes: constraints and opportunities. Agriculture and Human Values. 1998;15:325-36.

CDIR. California Code of Regulations, Title 8, Section 3456:Hand-held tools. Sacramento: California Department of Industrial Relations; 2005.

Ceesay J. Soil survey report- Gunjur Women's Vegetable Garden. Unpublished report. Soil and Water Management, Department of Technical Services, Yundum, Western Division, The Gambia; 2009.

Ceesay K. Personal interview. Gunjur- Fayunko women's vegetable garden advisor. October 28, 2008. Gunjur- Fayunko women's vegetable garden, Gunjur, The Gambia.

Chatizwa I. Mechanical weed control: The case of hand weeders. In: Proceedings of the 1997 Brighton Crop Protection Conference: Weeds; 1997 Nov 17-20; Brighton, UK. 1997. p. 203-8.

Creswell J, Plano Clark V, Gutmann M, Hanson W. Advanced mixed methods research designs. In: Tashakkori A, Teddlie C, editors. Handbook of mixed methods in social and behavioral research. Thousand Oaks, California: Sage; 2003. p. 209–40.

Creswell JW. Research design: qualitative, quantitative, and mixed methods approaches. Thousand Oaks, California: Sage; 2009.

Culp K, Kuye R, Donham K, Rautiainen R, Umbarger-Mackey M, Marquez S. Agricultural-related injury and illness in The Gambia: a descriptive survey of a rural nursing service and area farmers. Clinical Nursing Research. 2007;16(3):170-94.

Culp K, Marquez SP, Bobb M, Jagne DM. An inaugural conference on occupational health in The Gambia: Exploring the world through international occupational health programs. American Association of Occupational Health Nurses Journal. 2005; 53(2):65-71.

DeRoo LA, Rautiainen RH. A systematic review of farm safety interventions. American Journal of Preventative Medicine. 2000; 18(4S):51-62.

Earle-Richardson G, Jenkins P, Fulmer S, Mason C, Burdick P, May J. An ergonomic intervention to reduce back strain among apple harvest workers in New York State. Applied Ergonomics. 2005;36(3):327-34.

Egharevba R, Iweze F. Sustainable agriculture and rural women: Crop production and accompanied health hazards on women farmers in six rural communities in Edo State Nigeria. Journal of Sustainable Agriculture. 2004;24(1):39-51.

Fabunmi A, Aba S, Odunaiya N. Prevalence of low back pain among peasant farmers in a rural community in south west Nigeria. African Journal of Medicine and Medical Sciences. 2005;34(3):259-62.

Fathallah FA, Miller BJ, Miles JA. Low back disorders in agriculture and the role of stooped work: Scope, potential interventions, and research needs. Journal of Agricultural Safety and Health. 2008;14(2),221-45.

Faucett J, Meyers J, Miles J, Janowitz I, Fathallah F. Rest break interventions in stoop labor tasks. Applied Ergonomics. 2007;38(2):219-26.

Food and Agriculture Organization of the United Nations (FAO)/ International Fund for Agricultural Development (IFAD)/Government of Japan. Agricultural implements used by women farmers in Africa. [Internet]. 1998 [cited 2006 Nov 6]. Available from: http://www.ifad.org/pub/other/!ifadafr.pdf.

Food and Agriculture Organization of the United Nations (FAO). Appropriate water-lifting technologies in West Africa. [Internet]. 2004 [cited 2009 June 9]. Available from: http://www.fao.org/docrep/008/y5891e/y5891e00.HTM.

Food and Agriculture Organization of the United Nations (FAO). ProdSTAT database. [Internet]. 2008 [cited 2009 June 6]. Available from: http://faostat.fao.org/

Glaser B, Strauss A. The discovery of grounded theory: strategies for qualitative research. Chicago: Adline Publishing Company; 1967.

Hellin J, Bellon M, Badstue L. Bridging the gaps between researchers' and farmers' realities. Low External Input Sustainable Agriculture (LEISA) Magazine 22(3). [Internet]. 2006 [cited 2008 Feb 6]. Available from: http://www.leisa.info/index.php?url=show-blob-html.tpl&p[o_id]=85340&p[a_id]=211&p[a_seq]=1.

Hurst P, Termine P, Karl M. Agricultural Workers and their Contribution to Sustainable Agriculture and Rural Development. [Internet]. 2005 [cited 2007 November 5]. Available from: http://www.fao.org/docrep/008/af164e/af164e00.htm.

International Labor Organization (ILO). Safework programme on safety, health and the environment. safety and health in agriculture. Geneva: Safework, ILO; 2000.

International Labor Organization (ILO). Working conditions: Agricultural workers (WIND). [Internet]. 2005 [cited 2007 October 8]. Available from: http://www.ilo.org/public/english/protection/condtrav/workcond/agriwork/agricult.htm.

Janowitz I, Tejeda DG, Miles J, Duraj V, Meyers J, Faucett J. Ergonomics interventions in the manual harvest of wine grapes. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting; 2000. p. 628-30.

Kaul R. Labour in agricultural production in Asia and Africa and the need for ergonomic interventions. In: Proceedings of the XXV CIOSTA-CIGR V Congress: farm planning, labour and labour conditions, computers in agricultural management; 1993; Wageningen, the Netherlands. 1993. p. 20-27.

Kaul R, Ali A. Gender issues in African farming 1: A case for developing farm tools for women. Journal of Farming Systems Research and Extension. 1992;3(1):35-46.

Kuye R, Donham K, Marquez S, Sanderson W, Fuortes L, Rautiainen R, Jones M, Culp K. Agricultural health in The Gambia I: agricultural practices and developments. Annals of Agricultural and Environmental Medicine. 2006a;13(1):1-12.

Kuye R, Donham K, Marquez S, Sanderson W, Fuortes L, Rautiainen R. Agricultural health in The Gambia II: A systematic survey of safety and injuries in production agriculture. Annals of Agricultural and Environmental Medicine. 2006b;13(1):119-28.

Meyers JM, Miles JA, Faucett J, Janowitz I, Tejeda DG, Kabashima JN. Ergonomics in agriculture: Workplace priority setting in the nursery industry. American Industrial Hygiene Association Journal. 1997;58(2),121-26.

Morgan D. Focus groups as qualitative research- Second Edition. Beverly Hills: Sage Publications; 1997.

Muruka AO. Age, height, and duration of service in relation to back pain among tea pickers in Kenya. Afr Newsletter on Occup Health and Safety. 1998;8(3):60-1.

Nag PK, Chatterjee SK. Physiological reactions of female workers in Indian agricultural work. Human Factors. 1982. 23(5):607-13.

Nag PK, Nag A. Drudgery, accidents and injuries in Indian agriculture. Industrial Health. 2004;42(2):149-55.

Nag P. Occupational workload of Indian agricultural workers. Ergonomics. 1980;23(2): 91-9.

Naidoo RN, Haq SA. Occupational use syndromes. Best Practice Research Clinical Rheumatology. 2008;22(4):677-88.

National Women Farmer's Association of The Gambia (NAWFA). Five Year Programme Strategy: January 2007- December 2011. Serrekunda, The Gambia:NAWFA; 2007.

National Institute of Occupational Safety and Health (NIOSH). Injuries among farm workers in the United States- 1995. Atlanta, Georgia: Centers for Disease Control (CDC); 2001.

Nwuba E, Kaul R. The effect of working posture on the Nigerian hoe farmer. Journal of Agricultural Engineering Research. 1986;33(3):179-85.

O'Neill DH. Ergonomics in industrially developing countries: does its application differ from that in industrially advanced countries? Applied Ergonomics. 2000;31:631-40.

Peterson R. Constructing effective questionnaires. Thousand Oaks: Sage Publications; 2000.

Ramahi A, Fathallah F. Ergonomic evaluation of manual weeding practice and development of an ergonomic solution. In Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting; 2006; San Francisco, California. p.1421-5.

Ramana C, Ananthakrishnan D. Modified handhoe handle for operational comfort. Indian Journal of Dryland Agricultural Research and Development. 2002;17(1):28-32.

Rivilis I, Van Eerd D, Cullen K, Cole DC, Irvin E, Tyson J, Quenby M. Effectiveness of participatory ergonomic interventions on health outcomes: A systematic review. Applied Ergonomics. 2008;39(3):342-58.

Rogan A, O'Neill D. Ergonomics aspects of crop production in tropical developing countries: A literature review. Applied Ergonomics. 1993;24(6);371-86.

Rogers E. Diffusion of innovations. New York: Free Press; 2003.

Rosecrance J, Cook T. The use of participatory action research and ergonomics in the prevention of work-related musculoskeletal disorders in the newspaper industry. Applied Occupational and Environmental Hygiene. 2000;15(3):255-62.

Sanders D. Vegetable Crop Irrigation. [Internet]. 1997 [cited 2009 June 09] Available from: http://www.ces.ncsu.edu/depts/hort/hil/hil-33-e.html

SAS Institute Inc. General estimating equations. [Internet]. 2008 [cited 2008 February 8] Available from: http://support.sas.com/rnd/app/da/new/dagee.html.

SAS Institute Inc. The GENMOD procedure. [Internet]. 2009 [cited 2009 April 30] Available from: http://support.sas.com/documentation/cdl/en/statug/59654/HTML/default/genmod_toc.htm.

Seck A. Personal interview. Concern Universal horticultural expert. June 20, 2007. Concern Universal Gambia headquarters, Fajara, The Gambia.

Tewari V. Evaluation of three manually operated weeding devices. Applied Ergonomics. 1991;22(2):111-6.

United Nations Development Program (UNDP). Human Development Indices: A statistical update 2008 - HDI rankings. [Internet]. 2008 [cited 2009 June 6] Available from: http://hdr.undp.org/en/statistics/.

Vanderwal L, Rautiainen R, Kuye R, Donham K, Peek-Asa C, Cook T, Ramirez M, Culp K. Improving the health and safety of women vegetable farmers in The Gambia (West Africa). In Proceedings of the National Institute for Farm Safety 2009 Summer Conference. Technical paper 09-06. 2009 June 14-18; New Orleans, Louisiana; 2009.

Villarejo D, Baron S. The occupational health status of hired farm workers. Occupational Medicine: State of the Art Reviews. 1999;14(3):613-35.

Vink P, van Eijk DJ. The effect of a participative product design process on user performance. Safety Science. 2007;45(5):567-77.

Violante F, Kilbom Å, Armstrong TJ. Occupational ergonomics: Work related musculoskeletal disorders of the upper limb and back. New York: Taylor & Francis; 2000.

Zeger S, Laing K. Longitudinal data analysis for discrete and continuous outcomes. Biometrics. 1986;42(1):121-30.