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FUNCTIONAL DESIGN OF PESTICIDE PROTECTIVE GLOVES: AN EXPLORATORY STUDY OF METHODOLOGIES AND ANALYSES OF MOVEMENT

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Teresa Ann Bellingar

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M.A. degree in Clothing & Textiles

Ann C. Slocum
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FUNCTIONAL DESIGN OF PESTICIDE PROTECTIVE GLOVES: AN EXPLORATORY STUDY OF METHODOLOGIES AND ANALYSES OF MOVEMENT

By

Teresa Ann Bellingar

A THESIS

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ABSTRACT

FUNCTIONAL DESIGN OF PESTICIDE PROTECTIVE GLOVES: AN EXPLORATORY STUDY OF METHODOLOGIES AND ANALYSES OF MOVEMENT

By

Teresa Ann Bellingar

The first purpose of this study was to determine if pesticide protective gloves inhibit a worker's movements while completing two typical tasks. Data were collected using high speed cinematography. The three-dimensional data was graphed and compared. The graphs showed that the glove appeared to decrease abduction/adduction and supination/pronation ranges that the hand could complete.

Secondly, the relationship between applicators' hand shape & size, glove size & design, glove type, and how applicators don and doff gloves was examined. This was completed by measuring applicators' hands and gloves and videotaping them donning and doffing gloves. Data indicated that glove sizes are not consistent across materials, do not fit accurately, and that not all applicators don and doff their gloves identically.

Additionally, the usefulness of different methodologies to examine motion was assessed. Both high speed cinematography and videotaping appear to be useful for examining motion functional clothing design.

To my Mom and Dad
for their love, support, generosity,
and most of all for their belief in my
abilities to achieve all that I want to accomplish

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Chapter One

INTRODUCTION

Over the years, the application of pesticides on crops and lawns by agricultural and urban workers has steadily increased. Presently, 2.7 billion pounds of pesticides are being used in the United States each year (NC 170 Proposal, 1988, p. 1). The number of persons applying pesticides also has increased as new businesses such as lawn care have developed. With the increase in pesticide application and the number of persons applying pesticides, protection of the applicator has become a concern. Short term health risks from pesticide exposure include nausea, diarrhea, rashes, headaches, and eye irritations. Long term health risks for those in contact with pesticides are still unclear, but pesticides generally are suspected of effecting the brain, heart, liver, kidney, lung, blood and reproductive organs. They are thought to cause accelerated atheroscelrosis, hypertension and impaired immunities and to form carcinogens and teratogens (Morgan, 1980, p. 98,100).

Pesticide enters the body by way of three avenues (1) inhalation, (2) ingestion, and (3) dermal exposure. The main avenue of exposure, particularly for liquid sprays, is the dermal route (skin absorption) (Grover, Cessna, Muir, Riedel, Franklin, & Yoshida, 1986; Maddy, Wang, & Winter, 1983; Moraski & Nielsen, 1985; Nigg, Stamper, & Queen, 1986; and Reinert and Severn, 1982). Typically, the greatest level of dermal exposure occurs at the hands. Studies have shown that 80% to more than

90% of the total dermal exposure occurs through the hands (Davis, 1980, p. 36; Grover, et al., 1986; and Moraski & Nielsen, 1985). These studies indicated that the "functional and practical limitations" of protective clothing, e.g. loss of dexterity when wearing gloves, work habits, and incorrect handling of pesticides, influence the amount of dermal exposure that occurs at the hands.

Researchers, therefore, suggested that applicators should wear gloves to decrease the absorption of pesticides through the hands. However, studies concerning the ability of gloves to provide protection have been inconclusive. Maddy, et al. (1983) found hand exposure exceeded exposure to all other parts of the body; however, hand exposure decreased from 90% to 40.9% of total exposure when gloves were worn. On the other hand, Nigg, et al. (1986) found that applicators reduce their dermal exposure 27% by wearing gloves and that mixer loaders actually increased their dermal exposure by an average of 9%. Nigg, et al. (1986) felt that this increase was probably due to the number of times gloves were removed by mixer loaders during their work day. Fenske (1988) found that when workers wore neoprene gloves the exposure to mixers' hands was 41% of their total dermal exposure and only 13% for the applicator (Fenske, 1988). Nigg, et al. (1986) and Fenske (1988), therefore, concluded that the job activity, such as mixing/loading or applying/spraying, could vary the amount of total dermal exposure. This also contradicted Maddy's, et al. (1983) conclusions that job activity did not contribute significantly to the total dermal exposure a pesticide worker received. Maddy included the

activities of mixing/loading and/or ground application, aerial application, and flagging. The difference may lie in the specific equipment used in the activities.

Maddy, et al. (1983), Nigg, et al. (1986) and Fenske (1988) have stated some reasons for continuing exposure of the hands while wearing gloves. These include the inside of the glove becoming contaminated from (1) donning and doffing gloves during work and (2) handling pesticides between donning and doffing gloves. Consequently, gloves are one area of study in a regional research project pertaining to pesticide exposure.

This study is part of North Central Regional Project 170, "Reducing Pesticide Exposure of Applicators through Improved Clothing Design and Care," and is supported by funds from the Michigan Agricultural Experiment Station. One of the overall purposes of the regional study is to "develop and/or evaluate textiles and protective clothing that meet users' physical, socio-psychological and economic needs" (NC 170 Proposal, 1988, p. 8). This phase of the Michigan study contributes to the needs assessment and evaluation of protective clothing. The author is a graduate research assistant for the Michigan portion of the study. The first purpose of this exploratory study was to analyze the kinematic motion of pesticide applicators' hands while performing typical tasks to determine if wearing protective gloves limits the range of motion of the hands. The methods for this three-dimensional kinematic analysis will be found in Chapter 4. Secondly, this study will examine if there is a relationship between applicators hand shape & size, glove size & design, glove type, and how applicators

don and doff gloves. This study will also determine the type of hand protection that campus applicators participating in this study are wearing and what problems they have with the gloves.

The information gained from this study has potential usefulness for any individual who applies or has contact with pesticides. These data obtained from this study can be used to design more accurately fitting gloves that allow workers more mobility while they are performing their tasks. The findings also can provide a procedure for removing protective gloves that reduces contamination of the hands.

Chapter Two

REVIEW OF LITERATURE

This chapter reviews literature that concerns both protective apparel and clothing and motion analysis. Specifically, the literature reviewed for protective apparel dealt with protective gloves and included recommendations concerning glove designs, usage and materials. Individuals in universities, cooperative extension services, and the U.S. government are all concerned about the problem of selecting the correct glove to reduce dermal exposure, and are researching this problem.

Another major concern for protective apparel is the mobility it allows the wearer. Having mobility while using a glove is a major concern because workers use their hands for a wide variety of tasks. The literature review for motion analysis of clothing dealt with the different ways that motion can be analyzed. It did not deal specifically with gloves because no study could be located that had completed motion analysis on gloves.

PROTECTION

Recommendations Regarding Design and Use of Gloves

Cooperative extension specialists have developed recommendations for glove usage when working with pesticides (Gulbrandson, 1983, p. 2;

Howe, 1985, p. 2; Howe & Stryker, 1985, p. 1-2; and Tschirley, 1986, p. 43). Their recommendations are that:

1. Gloves should reach at least halfway to the elbow.

2. Sleeves should be worn outside gloves so pesticide will not run down the sleeve into glove, unless working above the head, then the sleeves should be tucked inside the glove.

3. Gloves should be clean, dry, and free of holes and tears.

In addition, the U.S. government developed recommendations that included those developed by cooperative extension specialists (NACA, Cooperative Extension Service, & EPA, p. 1; Russell, 1981, p. 2-17; and Singer, 1982, p. 19,21). The additional recommendations are to:

1. Replace gloves often, even if they do not seem worn or contaminated.

2. Wear disposable gloves if they can resist penetration and puncturing or tearing during the period of use.

Recommendations Regarding Materials for Gloves

Conclusions drawn about materials for gloves (Williams, 1980; Hougaard, 1988; Nelson, Lum, Carlson, Wong, & Johnson, 1981; Weeks & Dean, 1977; and Henry, 1984) are fairly general. One of the main conclusions is that there is no material "available for universal protection from chemical contact" (Williams, 1980, p. 884). The reason being that "the permeation rate of a specific chemical varies for different materials and for materials having the same composition and thickness, but a different manufacturer" (Williams, 1980, p. 884). Hougaard (1988, p. 7) also states that because over 1000 different chemicals are used in about 100 countries that it is important ". . .that chemical protective equipment should be permeation tested

against the exact chemical it is expected to protect against." One guideline that researchers have suggested is that "the permeation rate of the solvent. . .[is]. . .inversely proportional to glove thickness for a given manufacturer's material" (Nelson, et al., 1981, p. 217). Williams (1979, p. 879) also found that "the protection of the glove increased with thickness" except when gloves were found to have "surface imperfections such as dimples and poorly coated seams." However, increasing glove thickness decreases a worker's hand dexterity. Therefore, glove thickness needs to be determined by the activities that the worker will be performing.

Williams (1979, p. 881) also found that repeated contact with chemicals can change protection given by the gloves. For example, "the PVC coated [glove] showed a reduction in both the chemical protection and physical properties [i.e. abrasion and tear resistance]" (Williams, 1979, p. 881). However, the neoprene glove did not change in physical properties and the protection it gave was increased. These results are believed to relate to each glove's material composition. Weeks and Dean (1977, p. 722) also believe that glove material contributes more to protection than the thickness of the material. An example they gave ". . .was the fact that 8 mil natural latex surgeon's gloves afforded a breakthrough time 2-3 times greater than 30 mil neoprene." Henry (1984, p. 53) showed that when exposed to chlorine, neoprene gloves showed structural deterioration but no breakthrough; the rubber only showed some brown discoloration. Therefore, the researchers previously cited have concluded that a complete testing of a proposed glove

material should be done for the particular chemical and work activity before adopting it for use.

Cooperative extension publications have compiled a list of recommended glove materials for use during pesticide application (Gulbrandson, 1983, p. 2; Howe, 1985, p. 2; Howe & Stryker, 1985, p. 1-2; and Tschirley, 1986, p. 43). Their recommendations are:

1. Wear liquid-proof, unlined neoprene or rubber gloves.

2. Avoid cotton or leather gloves or gloves with fabric lining because they absorb the pesticide.

The two materials that were mentioned most often for use with pesticides by the U.S. government were neoprene and rubber.

The U.S. government has also developed some categories of concern for protective clothing used against carcinogenic liquids that can be applied to gloves (Little, 1978, p. 8). They are:

1. Strength: tear, puncture, abrasion resistance and tensile strength

2. Chemical Resistance: strength degradation, permeation resistance

3. Thermal Resistance: strength degradation

4. Dexterity/Flexibility: dexterity (gloves), flexibility

5. Cleanability: decontamination, washability

6. Aging Resistance: U.V. resistance

Problems Associated with Recommendations for Gloves: Even though these recommendations have been made by researchers, pesticide users still find it difficult to determine what protective clothing to wear because of the number of different pesticides on the market. Ehntholt, Almeida, Beltis, Cerundolo, Schwope, Whelan, Royer, and Nielsen (1988,

p. 728) believe that a test should be developed ". . .that would rapidly eliminate inappropriate pesticide-glove combinations at the outset" so that "the number of time-consuming permeation tests that must be conducted" can be minimized. Ehntholt, et al. (1988, p. 730) note that "the degradation test. . .shows promise for use as a screening device to select resistant glove materials."

Training Employees in Proper Use of Pesticide Protective Clothing: Mansdorf (1988) feels that a comprehensive approach to chemical protective clothing use needs to be developed and that a training program needs to be implemented for employees of companies using protective clothing. Eiser (1988) and Hougaard (1988) also feel that training employees to select proper equipment and to follow safety regulations is essential. Hougaard (1988, p. 8) believes that workers using protective clothing ". . .should ask the suppliers of chemicals to give exact information about the type of personal protection to apply in specific cases." The State of Michigan recently revised its pesticide laws so that some training is required before an individual is allowed to spray chemicals. The new laws will require workers in the lawn care industry to be trained and to take safety measures, such as wearing protective clothing (Kerwin & Pfaff, 1989).

Goydan, Schwope, Lloyd, and Huhn (1988) suggest that workers wearing protective clothing refer to the Chemical Protective Clothing Data Base (CPC base) for the personal computer. The CPC base provides information about the breakthrough time, permeation rate, and weight-change information on clothing materials (Goydan, et al., 1988, p. 403). "Also included in the system are descriptions of the clothing

materials tested, their sources, and the literature references for the data" (Goydan, et al., 1988, p. 403). They stress, however, that the CPC base is not a clothing recommendation system but that it enables "industrial hygienists and safety specialists to reach informed decisions regarding clothing selection and specification."

Even with all these recommendations, many workers still are not wearing any protective clothing while using pesticides. The main reasons workers have given for not wearing protective clothing is that they find what is available on the market today does not fit properly, that it is unattractive, and most importantly that it is uncomfortable (Cloud, 1988; Coletta & Spence, 1985; Cowan, Tilley, & Wiczynski, 1988; DeJonge, Vredevoogd, & Henry, 1983/84; DeJonge & Munson, 1986; Eiser, 1988; Gittleman, 1988; Kamal, Sayed, Hassam, & Massoud, 1988; Keeble, Norton, & Drake, 1985; Moraski & Nielsen, 1985; Nigg, 1986; Pontrelli, 1977; Waldron, 1985). Another reason workers are not wearing protective clothing is because of the lack of specific information on chemicals at the consumer level.

It is apparent, therefore, that a need exists to develop protective clothing that offers protection but is acceptable to the wearer. The research reviewed to find recommendations for the pesticide applicator shows that there is no specific glove that will provide protection from all chemicals. Because of this, every glove needs to be tested with the specific chemical/pesticide which a worker must use. To date this specific testing has not been done for all gloves. Manufacturers have identified gloves that are usable with a broad array of chemicals, but do not name which materials to use with

specific chemicals. In their 1987 catalog for gloves, Edmont does include a list of recommendations on which material to use with a number of the more widely used chemicals. This information, however, is still not always available at the consumer or employee levels because the consumer or employee generally does not purchase protective clothing directly from the manufacturer. Although the CPC base is a step in the right direction, clothing recommendations need to be made for those workers who do not work in a company that has industrial hygienists or safety specialists. Especially important for the design of gloves, is the need for dexterity and sensitivity in addition to protection.

CLOTHING AND MOTION ANALYSIS

Relationship of Clothing to Mobility

Mobility is a key factor for clothing comfort and allowing the wearer to perform necessary functions. Mobility is particularly important for protective clothing because workers tend not to wear protective clothing that inhibits their movements. By inhibiting a worker's movements, it makes his or her job more difficult to complete. As Watkins (1984, p. 144) states, "If people don't have to work against their clothing, they can perform more effectively."

Generally, however, protective clothing loses its mobility as it provides greater protection. When testing the restriction effects of military clothing items on motor performance, Saul & Jaffe (1955, p. 14) found that "increases in the amount of clothing worn were associated with decrements in performance." Decreasing mobility with increasing protection occurs because of the thick layers of fabrics

that are generally needed to protect workers, as is the case with pesticide applicators' gloves. The gloves need to provide dexterity and flexibility to the workers but still be strong enough to resist tears, punctures, abrasion and permeation. Some studies showed that the use of protective gloves may decrease the wearer's ability to perform his/her tasks. Agricultural workers interviewed by Tremblay (1989, p. iv) stated that protective gloves presently available do not fit well, are uncomfortable, and interfere with fine manipulation. Thomas, Spencer, and Davies (1976) found that task times could increase up to 50% just from wearing gloves. Tremblay (1989, p. 65) also found that task times increased while wearing gloves. In addition, Tremblay (1989, p. 65) found that the thicker the glove the more time it took to complete a task. Williams (1979, p. 879) found that although thicker gloves provide more protection, they do inhibit the worker's hand dexterity. Bensel, Teixeira, and Kaplan (1987, p. iii) found that chemical protective (CP) gloves worn by Army personnel ". . .impaired manual dexterity capabilities and may also have interacted with other CP items to negatively affect performance of tasks requiring coordinated hand movements." Bensel, et al. (1987, p. 108) also ". . .expected that a reduction in glove thickness would result in dexterity performance when handwear is worn more closely approximately[ing] performance when the hands are bare." Sheridan (1954, p. 46) found that for typical, manual skills workers' main source or sources of impairment occurred at the ends of the glove fingers. Parsons and Egerton's (1985) study supported Sheridan's findings. In addition, their research found that in both thermally neutral and cold

environments that glove design can reduce finger mobility and therefore productivity.

The Relation of Donning and Doffing to Hand Exposure: Researchers have also suggested that the ease of donning and doffing gloves during work could increase hand exposure to pesticides (Fenske, 1988, p. 634; Maddy, et al., 1983, p. 3; Nigg, 1986, p. 127). One reason for this is that the inside of the glove apparently becomes contaminated when it is donned and doffed. The procedures an individual uses to don and doff and to handle pesticides may also be a cause for the contamination of the inside of gloves. One proposed solution to this problem is to increase the dexterity/flexibility of the protective gloves so that they are easier to don and doff. Therefore, the problem is to design a glove that provides protection but improves the dexterity/flexibility of the glove.

Anthropometric Studies Relating to the Hand: Another variable that may affect the mobility of the hand while wearing gloves is how well the glove fits the wearer's hands. Different body measurements have been identified that can be taken to classify individuals into percentile ranks. This allows researchers to determine the size of the average individual and, therefore, allows researchers to develop sizing charts. Anthropometric studies identify gender, age, occupation, and ethnicity as factors affecting an individual's anthropometric characteristics (Van Cott & Kinkade, 1972; Courtney, 1984).

Many different hand measurements can be taken depending on the problem that is being investigated. Garret (1971) presented data about the anthropometry and selected biomechanical characteristics of hands

compiled from five studies. This data was compiled ". . .to develop data necessary for Air Force equipment and manual work areas" (Garret, 1971, p. 117). The first two studies measured 56 dimensions of the hand for both men and women (Garret 1970a and b). The third study defined the neutral/relaxed position of the hand (Balcaen, 1969). The last two studied the spatial requirements for and the biomechanical capabilities of the hand (Garret, 1968; Garret, Alexander, & Bennet, 1967). From these studies, seven tables of data were developed providing a nearly complete anthropometric portrait of the hand. This data is viewed by Garret (1971, p. 129) as reflecting ". . .physical anthropology's viable and valuable contribution to human factors" and advises that human factors data of this type be incorporated into systems and product design.

Courtney (1984) completed an anthropometric study to see if any differences existed in the hand dimensions of Hong Kong Chinese women and other ethnic groups. Courtney (1984, p. 1169) measured 23 hand dimensions of 100 subjects for comparison with data from the United Kingdom, Japan, and the United States. Hong Kong women were found to have smaller hands than women from the United Kingdom and the United States, but larger hands than women from Japan.

As part of the regional NC 170 project, researchers at the University of Alberta, Edmonton studied hand morphology. Tremblay's research, directed by Dr. Betty Crown, focused on the evaluation of "the functional fit and comfort of commercially available gloves and . . .the joint effect of polymer type and thickness of glove materials on fit characteristics" (Tremblay, 1/89).

First, the hands of 380 agricultural workers were measured based on earlier studies by Van Cott & Kinkade (1972) and Courtney (1984). Tremblay took ten measurements of each hand (See Appendix A). From these measurements the two key hand dimensions identified were: hand circumference at metacarpal and length of the middle finger. One additional measurement that Tremblay took was from the tip of the index finger to the crotch of the thumb. Her study indicated that subjects had a problem with gloves fitting at that location. Another useful measurement is hand length which is measured from the crease of the wrist to the top of the middle finger. From the measurements taken, Tremblay found that "although percentiles are useful to describe the range of sizes for one dimension, this information does not give us an idea of the various shapes of hands. For example, it would be misleading to assume that an individual with a 50th percentile hand circumference will have a 50th percentile hand length" (Tremblay, 3/16/89).

Functional fit and comfort were then evaluated by selecting 38 farmers from the anthropometric survey, they were selected to be "representative of the user population's hand circumference and length of middle finger," to participate in "subjective evaluations of the goodness of fit of the test gloves" and in standardized dexterity tests (Tremblay, 1989, p. iv-v). "Significant differences in functional fit and comfort were found among gloves differing in polymer type, thickness and manufacturer." In the completion of the standardized tests, the tight fitting gloves "interfered the least with finger dexterity" (Tremblay, 1989, p. v). Overall, Tremblay (1989, p. v)

found that major design and sizing problems existed in the four styles of gloves that were tested.

Analysis of Movement

". . .Before a designer can create garments that provide for ease of movement, he or she must know what kinds of body movements take place in a particular activity" (Watkins, 1984, p. 144). Activities, though, can be made up by a number of different movement patterns. "Therefore, it is important to find ways to determine the movements of the particular group for which clothing is being created" (Watkins, 1984, p. 144). When designing gloves, for pesticide workers, therefore, the designer needs to be concerned mainly with the movements of the hand and wrist. Movements that the hand will be completing at the wrist joint will be flexion, extension, hyperextension, abduction (radial flexion), adduction (ulnar flexion), and circumduction. Pronation and supination occur at the forearm (Wells & Luttgens, 1976, p. 126; Watkins, 1984, p. 149), (See Definition of Terms).

Beginning a study of movement involves first ". . . identifying the aspects of movement that are most critical to a person's activities" (Watkins, 1984, p. 151). While individuals in the clothing and textiles field have studied motion, it has mainly been by observation. Other fields that have completed motion studies using more precise measurement are anthropology, aerospace science, biomechanics, medicine, psychology, rehabilitation, and dance. Individuals in the clothing and textiles field, therefore, should examine these techniques to see if motion studies of these types would be useful for clothing design.

Movement Notation: Some of the techniques used by these fields were identified by Watkins (1984) in her book Clothing the Portable Environment. Movement notation was discussed first. Movement notation collects ". . .data by notating or recording body movements on paper so that movement data from many participants can be compared and a complete cycle of movements can be charted. "Movement notation requires a 'language,' whether it be one of words, numbers or others symbols" (Watkins, 1984, p. 153). Two specific types of movement notation generally used in dance are Labanotation and Benesh notation. Other types of movement notation are kinesics basic notation to record basic body movements and a system developed by Roebuck (1968) for the space industry. Roebuck's (1968, p. 79) system is a simplified model of man based on a combination of vector and link concepts that "describe body positions in terms of orientation of limbs with respect to a tri-planar angular coordinate system conceived as attached to the pelvic region."

Movement of Joint Angles: Another technique used in movement studies alone or in combination with movement notation is the measurement of joint angles. The measurement of ". . .the precise joint angles needed to perform a specific activity. . .[is sometimes necessary]. . .in order to translate the data collected in movement notation into information useful for designing clothing" (Watkins, 1984, p. 161). These measurements can be taken by a variety of instruments. One instrument is the goniometer; it is ". . .a simple two-armed tool used by physicians and physical therapists to measure the number of degrees of motion at a joint" by placing the "central

pivot point of the goniometer. . .at the center of the joint axis" (Watkins, 1984, p. 161; Winter, 1979, p. 12). A Leighton Flexometer or gravity goniometer measures joint angles while strapped to the individuals' joint, and an electro goniometer measures joint angles electronically (Watkins, 1984, p. 161,162). A variety of photographic techniques can also be used to measure joint angles. Photographic techniques used to record these movements are light tracing photography, still photography, stroboscopic photography, optoelectric techniques, videotaping, or high speed cinematography, e.g. motion picture film (Higgins, 1977, p. 134).

Watkins (1977) completed a study which dealt with the body movements hockey players use to perform their specific tasks. In order to analyze these movements, Watkins (1977, p. 161) first ". . . determined the degree of movement needed in specific joint areas" by watching training and game films. Watkins (1977, p. 161) then chose two to five activities from those observations ". . .for each body movement as key activities to use in observing maximum degree of movement." If the hockey players were facing the camera, their joint angles were estimated from figures traced off the film. If the hockey players were not facing the camera, wooden figures were used to mimic their body positions, and the joint angles were measured off the model.

Watkins' (1977, p. 163) movement study also measured "the effects of movement on a total body covering. . ." for hockey players. To measure this, photographs were taken of a live model demonstrating the positions which reflected the maximum movements identified from the previous observations. Notes were taken from these photographs about

the fit of the body covering and used to make diagrams ". . .showing the location of elongation or contraction for each movement" (Watkins, 1977, p. 164). The designer then used this information to plan the placement of non-stretch features in hockey players' equipment.

Another study completed in the Clothing and Textiles field by Huck (1988) was concerned with the restriction of mobility a person encountered while wearing protective clothing systems. In this study, Huck (1988, p. 186) used a Leighton Flexometer to measure ". . .eight joint movements that represented the types of physical activity a fire fighter might encounter during the course of performing his fire fighting duties." Huck (1988, p. 186) measured the range of movement that the fire fighter was able to accomplish in his station uniform to use as a baseline value and then in different variations of protective clothing and equipment. The ". . .restriction in movement imposed by the protective clothing was calculated by subtracting the baseline value from the value measured when subjects wore protective clothing and equipment over the station uniform" (Huck, 1988, p. 187). The data was then used to evaluate possible changes needed in the protective clothing so that the wearer's mobility was not as restricted.

<u>High Speed Cinematography</u>: "The use and importance of cinematography to the person involved in movement are threefold: (1) to record an activity for future reference, (2) to use films for the strategical analysis of games, and (3) to use films in the qualitative and quantitative analysis of human performance" (Ulibarri, 1984, p. 1).

Completed studies that have used this technique are mainly in the field of biomechanics. Two studies examined foot motion during running

to help evaluate new athletic shoes for Brooks (Soutas-Little, Beavis, Verstraete, & Markus, 1987a; Soutas-Little, Ulibarri, Goodman, & Hull, 1987b). These studies were concerned with the difficulty of predicting the performance of athletic shoes because of the differences that exist in individual anthropometrics. This has led to consumers being ". . . subjected to confusing comparisons of pronation, supination, rear-foot motion, stiffness, flexibility and shock absorption" (Soutas-Little, et al., 1987b, p. 18). Biomechanists, however, can obtain "general characteristics of athletic shoes. . .by using a combination of biomechanical gait and engineering design analysis. . .[so that they can determine]. . .how to characterize shoe performance" (Soutas-Little, et al., 1987b, p. 18).

To gather this information, these studies filmed and digitized three footfalls from experienced male runners done on a treadmill. The filming was done by using "two high-speed. . .cine cameras in a stereo configuration giving lateral and rear views to both cameras" (Soutas-Little, et al., 1987a, p. 286). The points that were digitized were targeted at three locations on the shank and three locations on the foot or shoe. The data were then ". . .analyzed to obtain three-dimensional target information and angular values using rearfoot motion and the joint-coordinate system" (Soutas-Little, et al., 1987a, p. 287). This information, therefore, will be used to help improve the design of athletic shoes and to provide technical information to consumers that they will be able to understand.

Another study in the field of biomechanics looked at gait characteristics in the older adult (Ulibarri, Popsidero, Soutas-Little,

Verstraete, & Peltier, 1987). Gait characteristics of the elderly are being studied because "quantifiable biomechanical parameters of gait can assist in identifying instability and serve as a diagnostic tool for clinicians" (Ulibarri, et al., 1987). To gather data, Ulibarri, et al. (1987) used two high-speed cine cameras ". . .placed at angles to the plane of gait and a force plate." Seventeen targets were used and were placed on anatomical landmarks on the lower limb of the subjects. Three-dimensional target data of the seventeen targets were obtained by using direct linear transformation. The kinetic analysis performed on the data determined the center of pressure on the foot. Also calculated were "joint forces and moments in the sagittal plane. . .for the ankle, knee and hip" (Ulibarri, et al., 1987).

The preliminary results indicated measurable differences between older and younger populations. Previous problems that had been identified for the elderly were loss of strength in the legs and ankle weakness which appeared to lead to poor balance (Imms & Edholm, 1979; Whipple, Wolfson, & Ancerman, 1987, respectively). This information combined with the information obtained in Ulibarri's, et al. (1987) study is beneficial for Clothing and Textiles professionals because it gives them scientific evidence that wearing high heels could be hazardous for the elderly because of the instability that may exist in their gait.

Gehlsen and Albohm's (1980, p. 89) study evaluated sports bras to determine which style best minimized ". . .breast movement and discomfort during strenuous activity." To complete this study, Gehlsen and Albohm (1980, p. 90) ". . .used a Locam [sic.] camera with an

internal timing device to film the jogging subjects at 100 frames/sec. The film was analyzed on a Van Guard Motion Analyzer." This differs from the technique used by Soutas-Little, et al. (1987a; 1987b) and Ulibarri, et al. (1987) because it produced two-dimensional data instead of three-dimensional data for evaluation. The linear displacement that each bra allowed was found by measuring the vertical and horizontal displacement of the body and the breast from reference points located at the left clavicle and placed over the bra at the center of the breast during one running stride (Gehlsen & Albohm, 1980, p. 92). The average velocity for breast movement was determined by dividing the displacement values by the time of movement. "An analysis of variance statistic was used to determine the significance of differences in restraint of the sports bra" (Gehlsen & Albohm, 1980, p. 90).

Presently, only one study done in the Clothing and Textiles field has been located that used cinematography to study movement. Atkin (1980) used cinematography ". . .to analyze the body movements of people in wheelchairs" so that a method could be developed ". . .to use [the] data on body movement to develop rainwear designs for wheel-chair bound people." Atkin (1980, p. 79) selected "three activities of daily living which relate[d] to the design of rainwear. . .for further study." Cinematography was used to record these activities so that the researcher could obtain accurate quantitative measurements of movement. Atkin (1980, p. 80) used this method for data collection because ". . . it appeared to be the most appropriate method to collect the type of movement data required to develop appropriate criteria for garment

design." Before the filming, landmarks were established on the subject's body to be used in the film analysis. The landmarks were ". . .one and one quarter inch squares of highly reflective tape [that] were affixed to" joint centers of the shoulder, elbow, and wrist (Atkin, 1980, p. 83). The subjects were filmed completing the activities in the anterior and/or the lateral view. The film was then analyzed using a Vanguard Motion Analyzer to measure the ranges of motion that took place during the three activities (Atkin, 1980, p. 83). This study differed from those completed by Soutas-Little, et al. (1987a; 1987b) and Ulibarri, et al. (1987) in that the data was obtained and analyzed as two-dimensional data rather than three-dimensional data.

Chapter Three

STATEMENT OF PROBLEM

OBJECTIVES

One purpose of this exploratory study was to analyze the kinematic motion of pesticide applicators' hands while performing typical tasks to determine if wearing protective gloves limited the kinematic motion of the hands. Data were collected using high speed cinematography, and the kinematic analyses were completed by using existing software programs. Since cinematography has not been widely used in the Clothing and Textiles field to study motion, one goal of this research was to explore the usefulness of high speed cinematography and kinematic analysis to functional apparel designers.

The second purpose of this study was to study the motion involved in donning and doffing protective gloves and factors influencing it in order to identify the mechanism of internal glove contamination. Specifically, hand size and shape, type of glove, and glove size and design were examined. The motion of donning and doffing was recorded by videotaping the hands of pesticide applicators while they worked in the field. The motion of donning and doffing gloves was then analyzed by studying the videotapes. This study also determined the type of hand protection that campus applicators participating in this study are wearing and what problems they have with the gloves.

RESEARCH QUESTIONS

The following research question was tested using high speed cinematography and kinematic analysis:

1) Can differences in hand motions involving tightening and untightening container caps be differentiated between gloved and ungloved conditions by utilizing three-dimensional kinematic techniques?

The following research questions were tested using interviewing, anthropometrical and video taping techniques:

2) What types of hand protection, if any, do selected campus pesticide applicators use?

3) What problems do pesticide applicators identify with respect to hand protection?

4) What is the relationship between pesticide applicators' hand measurements and (a) other hand data and (b) glove size?

5) Is there a relationship between how pesticide applicators don and doff their gloves and glove design?

DEFINITION OF TERMS

Theoretical Definitions

Biomechanics: "The application of the principles and techniques of mechanics to the structure, functions, and capabilities of living organisms" (Guralnik, 1984, p. 142).

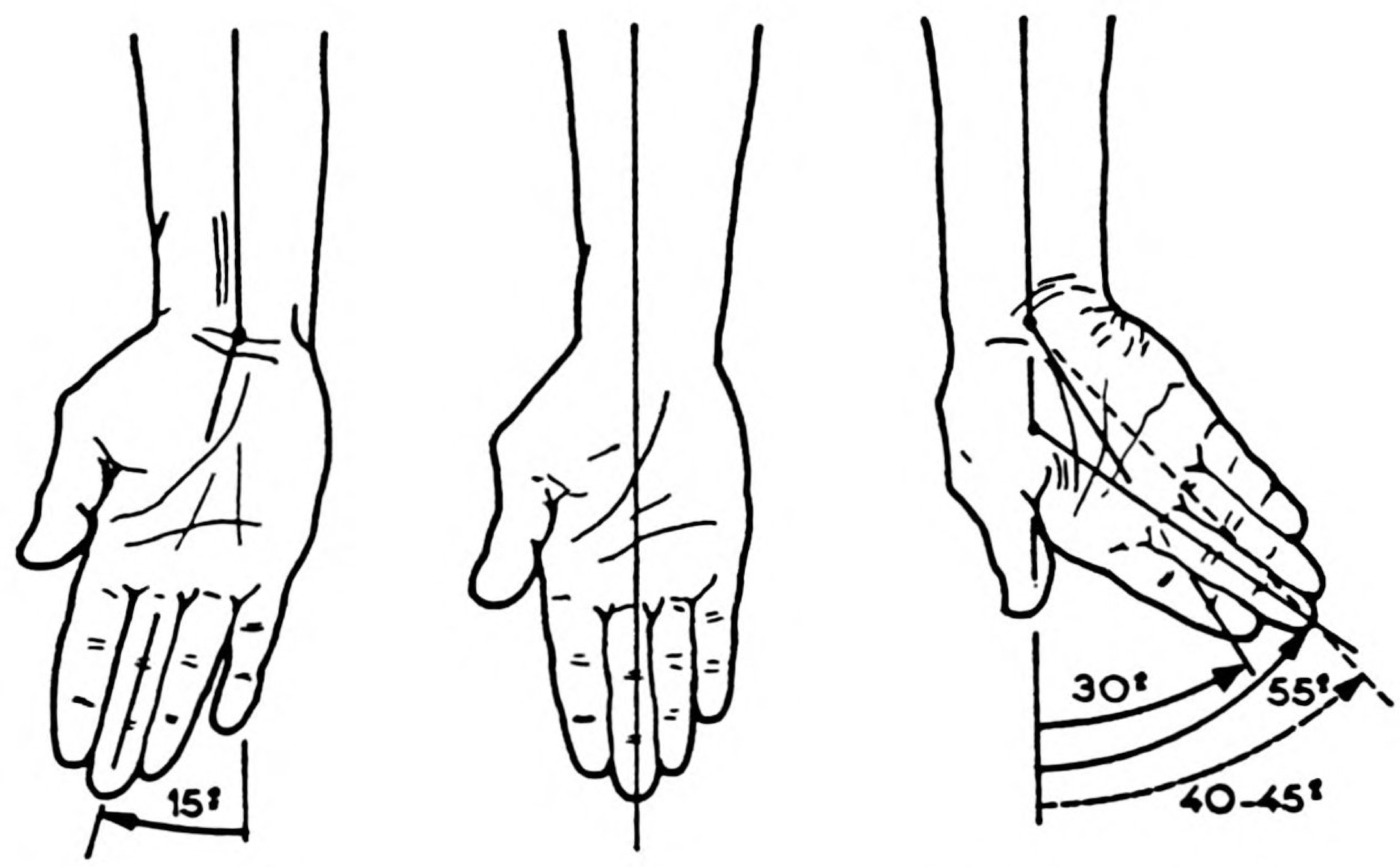
High Speed Cinematography: Making motion pictures with the use of special high-speed cameras that are capable of filming at a higher than normal rate (24 fps) (Ulibarri, 1984).

Kinematics: ". . .The geometry of motion. It describes the motion of bodies in terms of time, displacement, velocity, and acceleration. The motion occurring may be in a straight line (linear kinematics) or about a fixed point (angular kinematics). Kinematics is not concerned with the forces which cause the object to move" (Wells & Luttgens, 1976, p. 267).

Motion: ". . .The act or process of changing place or position. . .[relative]. . .to some reference point" (Wells & Luttgens, 1976, p. 267).

Abduction (radial flexion): The ". . .movement away from the midline of the body" (Watkins, 1984, p. 148).

Adduction (ulnar flexion): The movement towards the midline of the body (Watkins, 1984, p. 148).

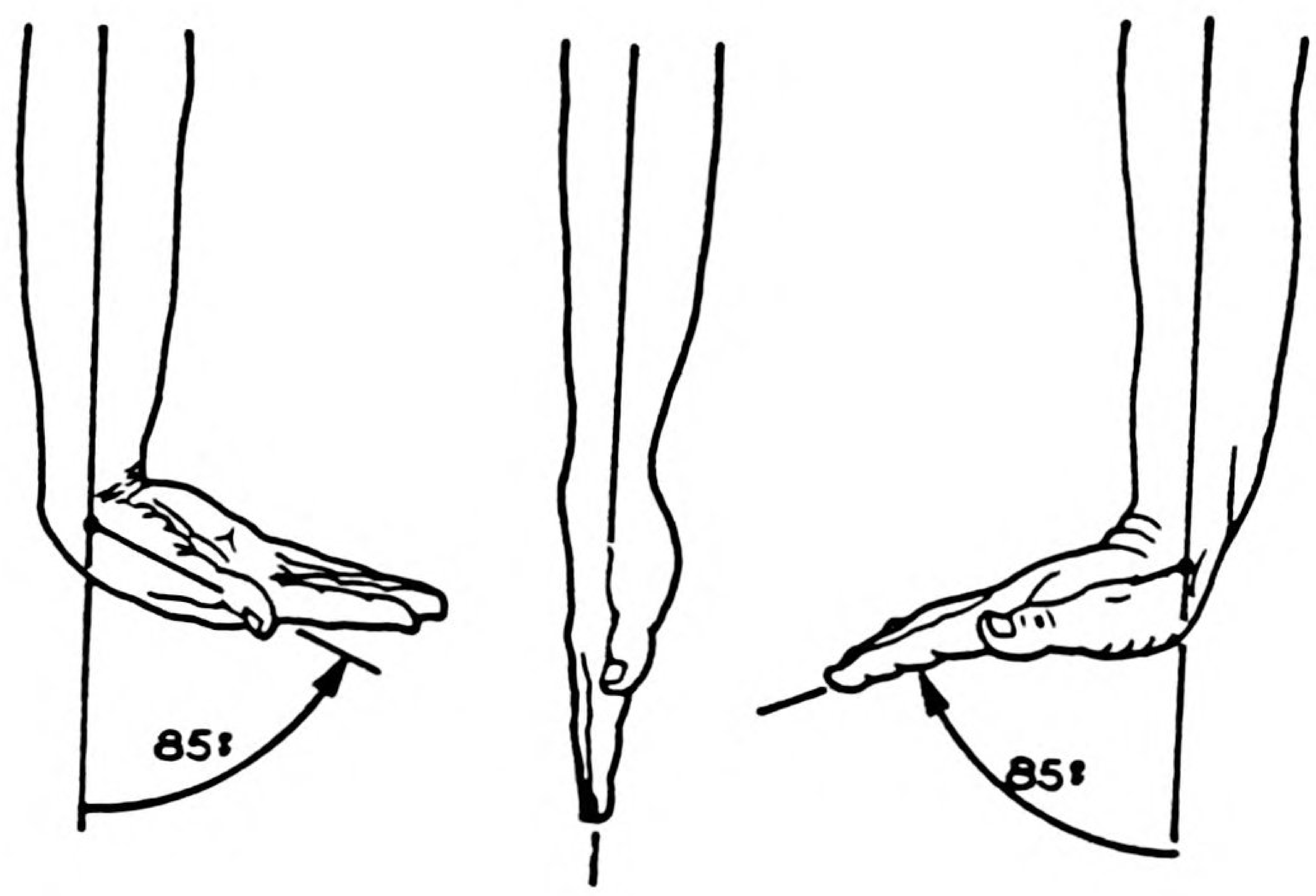


(Kapandji, 1982, p. 135)

Flexion: "The angle at the joint diminishes," bending (Wells & Luttgens, 1976, p. 23).

Extension: The angle at the joint increases, straightening (Wells & Luttgens, 1976, p. 23).

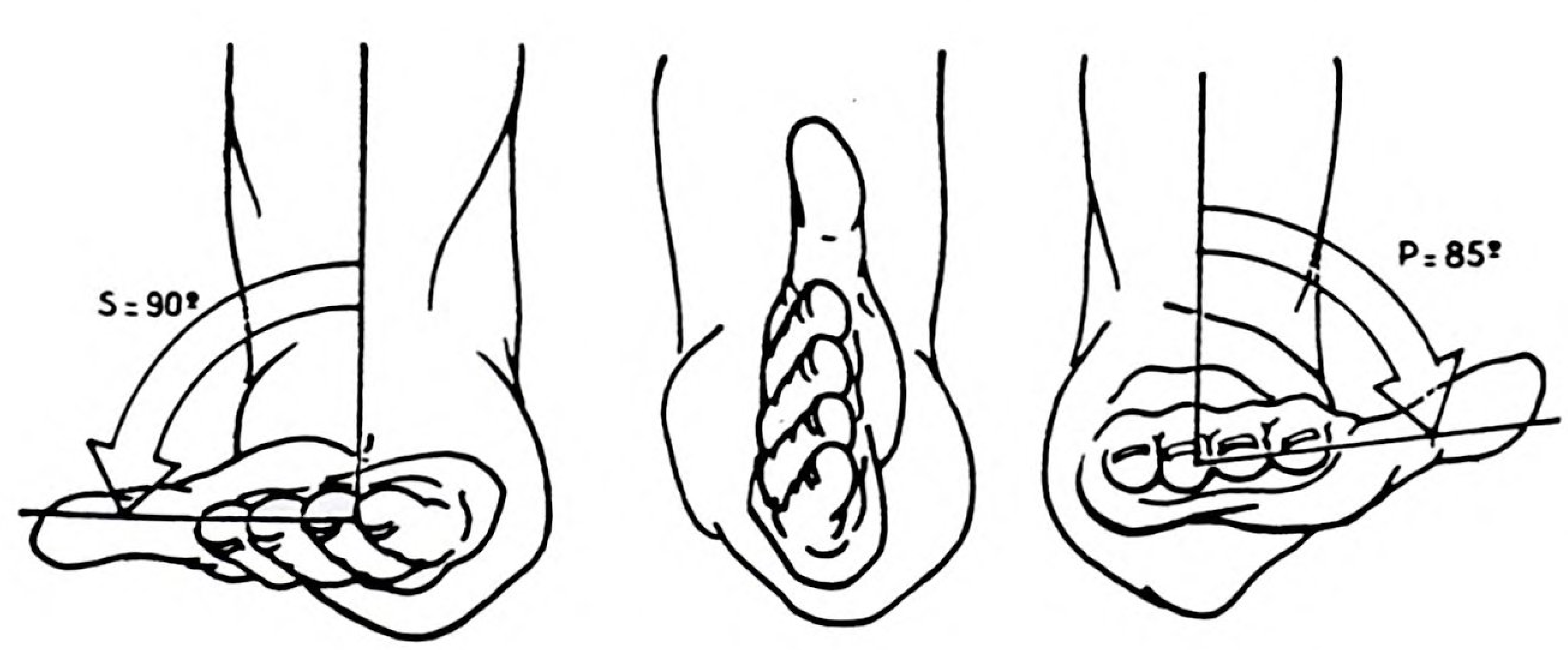
Hyperextension: "The continuation of extension beyond the starting position or beyond the straight line" (Wells & Luttgens, 1976, p. 23).



(Kapandji, 1982, p. 135)

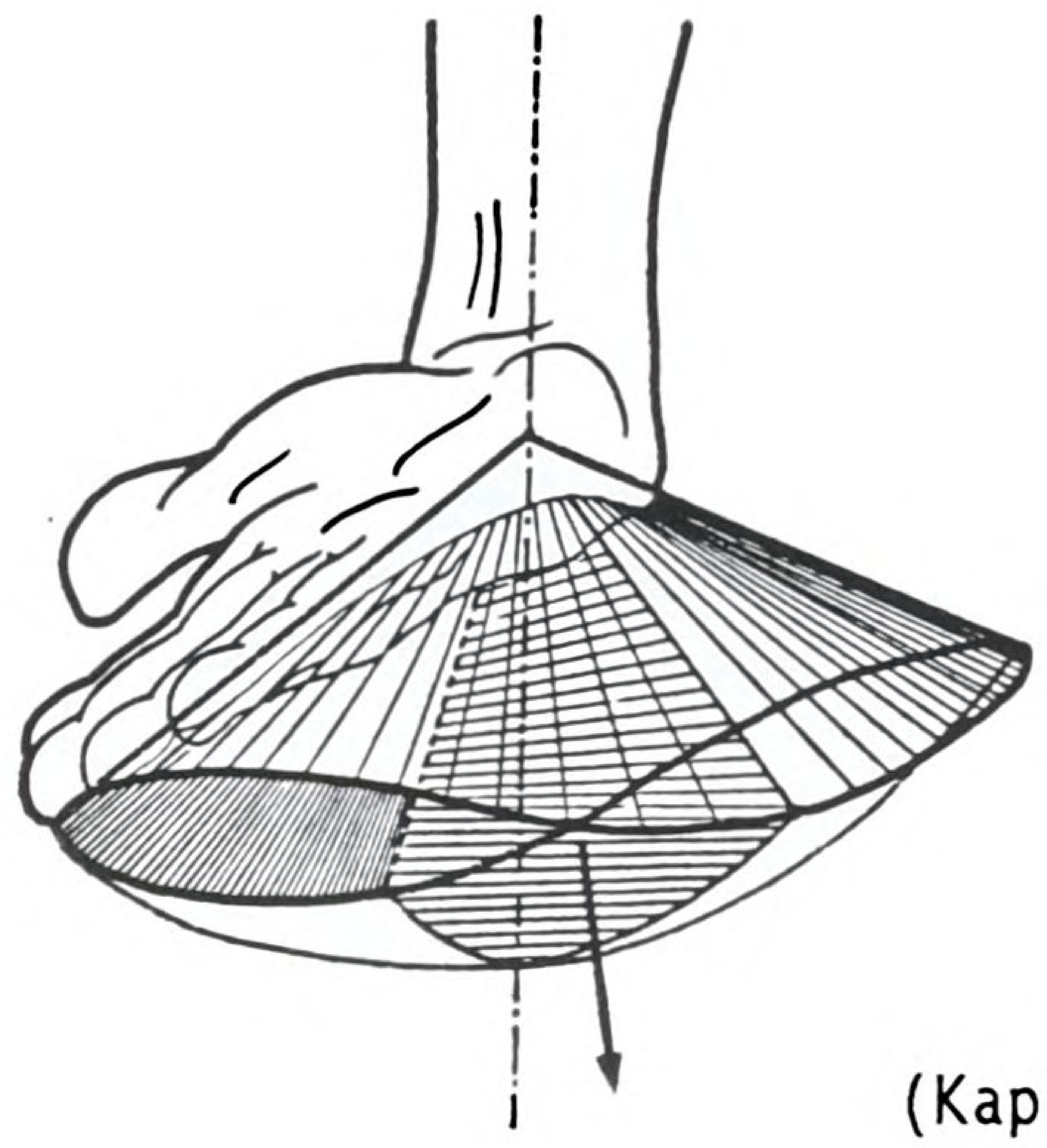
Supination (lateral rotation): Rotation of the forearm away from the trunk in anatomical position (Watkins, 1984, p. 147).

Pronation (medial rotation): Rotation of the foremarm towards the trunk in anatomical position (Watkins, 1984, p. 147).



(Kapandji, 1982, p. 101)

Circumduction: "A movement of the hand at the wrist whereby the fingertips describe a circle, and the hand as a whole describes a cone. It consists of flexion, radial flexion, hyperextension and ulnar flexion occurring in sequence in either this or reverse order" (Wells & Luttgens, 1976, p. 24).



(Kapandji, 1982, p. 133)

Glove Design: Determined by these characteristics of a glove: type of grip, shape of glove, type of cuff, and length of glove.

Glove Type: Determined by the glove material and the manufacturer and brand of the glove.

Pesticide Protective Gloves: Gloves that have been recommended for use with pesticides by either researchers, extension specialists, or glove manufacturers.

Operational Defintions

High Speed Cinematography: Two LOCAM cameras using 16 mm high speed film was shot at 64 fps, shutter angle was 120 degrees which gave an exposure rate of 1/190 seconds, and a frame time of 0.0156.

Glove for Cinematography: Pesticide protective gloves made from neoprene, 22 mil thick, 304.8 mm (12") long, manufactured by Pioneer, Stanzoil #N-44.

Hand Held Spray Gun Used in Cinematography: A spray gun that is usually attached to a hose and held in the hand. The trigger is pulled back by the fingers.

Pesticide Container Used in Cinematography: Lorox Plus 10 lb. display container. Lid circumference is 222.25 mm (8.75"), handle length is 114.3 mm (4.5"), and the space between the lid and the handle is 19.05 mm (.75").

Videotaping: Recorded on a Beta videocassette at the medium speed setting.

Disposable Glove for Videotaping: Prepowdered nonsterile, disposable glove for laboratory use made from vinyl, 12 mil thick, 254 mm (10") long, manufactured by Becton-Dickinson.

Reusable Glove for Videotaping: Pesticide protective gloves that were made from nitrile-latex, 18 mil thick, 304.8 mm (12") long, manufactured by North or made from butyl rubber, 18 mil thick, 279.4 mm (11") long, manufactured by Edmont.

Reusable Glove for Comparing Hand And Glove Measurements: Pesticide protective gloves that were made from nitrile, 22 mil thick, 330.2 mm (13") long, manufactured by Pioneer, Stansolv, #A-15.

Digit One: Thumb.

Digit Two: Index finger.

Digit Three: Middle finger.

Digit Four: Ring finger.

Digit Five: Little finger.

Doff: To remove.

Don: To put on.

Glove Size: One of the standard glove sizes, 9, 10 or 11, made by glove manufacturers.

Hand Shape and Size: Determined by taking ten measurements of the right hand as defined in Appendix A for the pesticide applicator's right hand.

Mil: "A unit of length, equal to 1/1000 inch" (Guralnik, 1984, p. 901).

MODEL OF STUDY

Problems such as this have been addressed using the human ecological model which was developed by Bubolz, Eicher, & Sontag, (1979). The human ecological perspective focuses on ". . .three central organizing concepts: [the] human environed unit (HEU), [the]

environment, and the interactions between and within these two" (Bubolz, et al., 1979, p. 28-29). The environment is further subdivided into the categories of natural environment, human constructed environment, and the human behavioral environment. The natural environment is "formed by nature with space-time, physical and biological components; the human constructed environment is. . .altered or created by human beings;" and the human behavioral environment is ". . .the environment of human beings and their biophysical, psychological, and social behaviors" (Bubolz, et al., 1979, p. 29-30). The interactions of these environments involves the ". . .relationship of reciprocal influence among a system's components" (Bubolz, et al., 1979, p. 30).

The model for this study consisted of two different HEU and selected components of the Natural Environment (NE) and the Human Constructed Environment (HCE). The two different HEUs for this study were volunteer male students from Michigan State University who performed typical tasks of pesticide applicators and volunteer campus pesticide applicators. The NE and the HCE were conceptualized as having subparts which interact with each other. For the Natural Environment, this included the space-time component; for the Human Contructed Environment, it was the socio-physical component. The interaction of these two environments and their effects on the Human Environed Units was the focus of this study and was illustrated in the conceptual model in Figure 1.

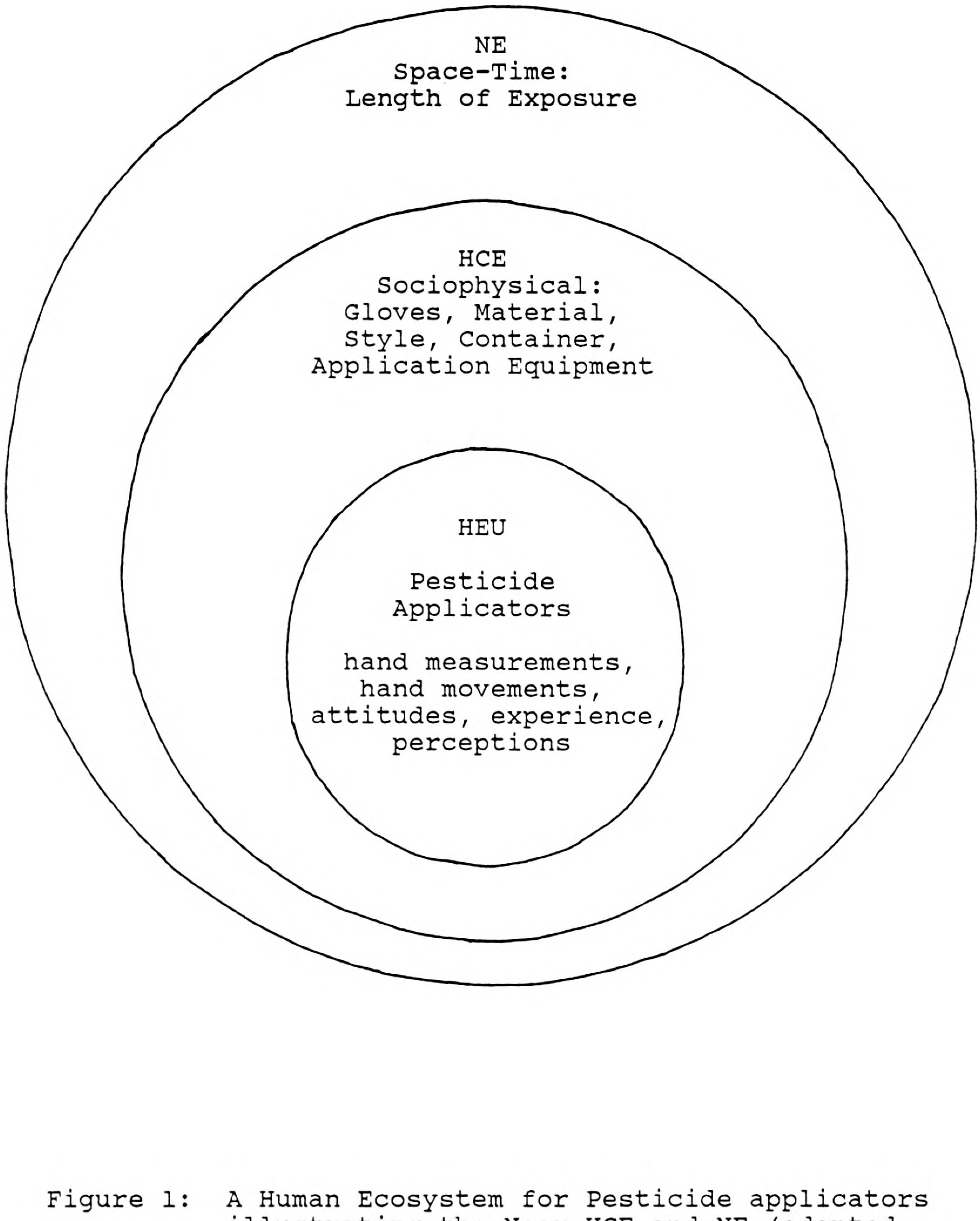


Figure 1: A Human Ecosystem for Pesticide applicators illustrating the Near HCE and NE (adapted from Bubolz, et al., 1979).

Interaction

Arrows on the adapted model indicate interaction. This study focused on the interface between the HEU, individuals working with pesticide containers and equipment who performed typical hand activities and pesticide applicators donning and doffing gloves, and the sociophysical component of the HCE, pesticide protective gloves. This study was concerned about the restriction of movement caused by the wearing of pesticide protective gloves while performing typical hand activities which duplicated pesticide applicators' movements associated with use. Therefore, the attitudes, experience, and perceptions of individuals working with pesticides will also be investigated. The Natural Environment could affect the individual while applying pesticides because a higher humidity level may cause more sweating to occur inside gloves and, thus, cause more donning and doffing of the gloves which could allow more pesticide to get near the skin. This probably would cause a greater amount of dermal exposure via the hands.

The human ecological model is conceptual and helps researchers to consider all of the facets involved in a problem. Since this was a functional clothing design problem a model of the design process developed by Branson (1982) also was included (See Figure 2). Branson's model explores two critical factors of design: the socio-psychological and the physical factor and shows in flow chart form the analytical thinking that is involved in the design process.

This study specifically was concerned about the "user reaction" component of the socio-psychological critical factor and the movement

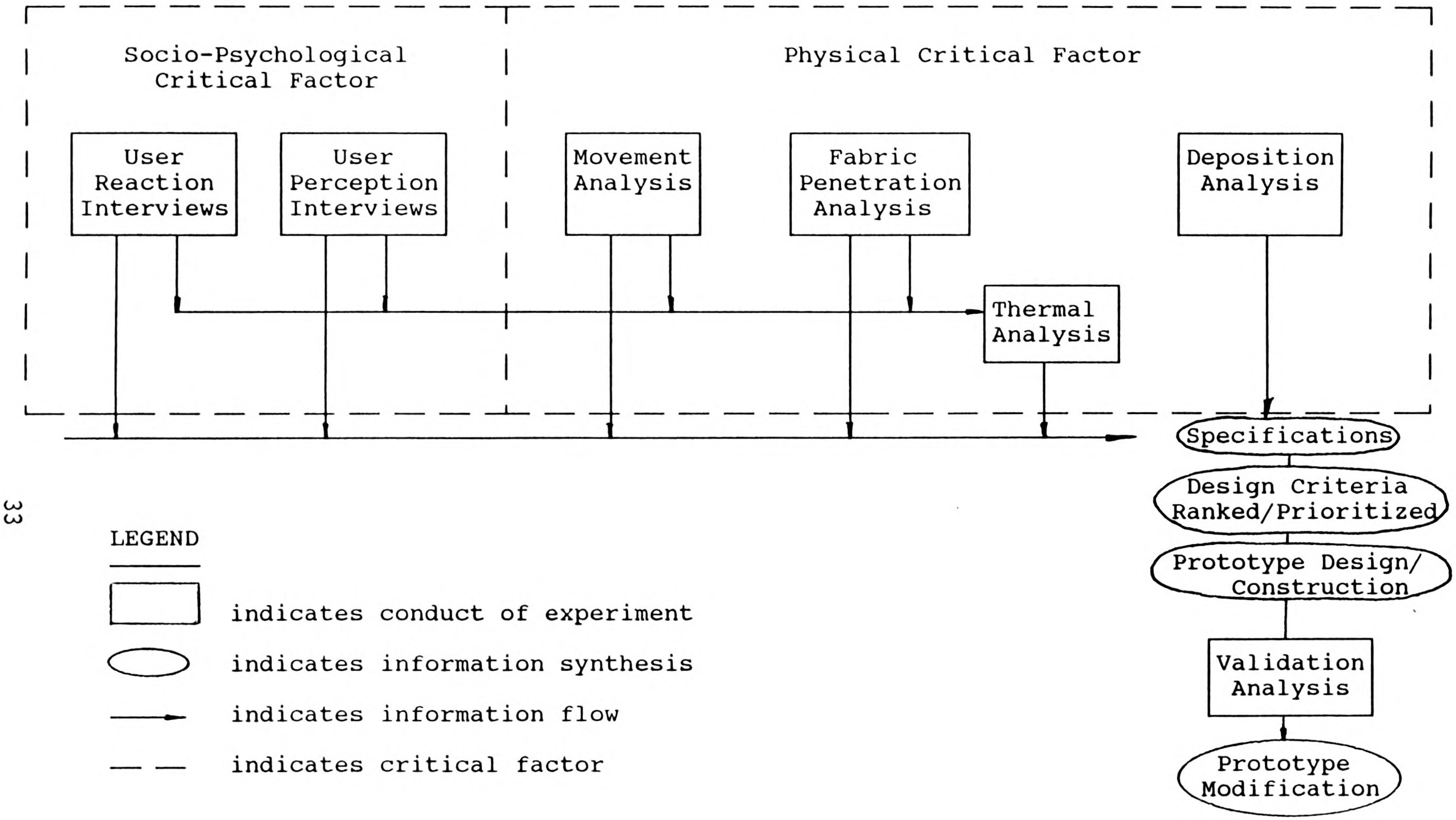


Figure 2: Activity/information interaction flow process for the development of functionally designed protective clothing for the agricultural worker (Branson, 1982, 22).

analysis component of the physical critical factor. A model, therefore, was adapted for this study that showed the relationship of the design process to the human ecological model (See Figure 3). For this study, the "user reaction interviews," provided information regarding what Michigan State University applicators wore for hand protection, when they wore gloves, and what problems they had with gloves, if any.

The gloves, themselves, were considered a "human constructed environment" that influenced how the applicators were able to perform their typical activities. The "movement analysis" component assisted in evaluating how the gloves, acting as an environment for the applicator, affected the performance of the applicators.

The "movement analysis" for those subjects involved in the portion of the study which used high speed cinematography to analyze motion, provided information about how protective gloves affected the movement of the hand while applicators performed identified typical tasks. The "movement analysis" for those subjects involved in the portion of the study which used videotaping to gather motion data, provided information on how to remove protective gloves so as to reduce hand contamination.

The information obtained from both the "user reaction interviews" and the "movement analysis" components along with information from other regional studies will contribute to the development of specifications for protective gloves. These specifications will be translated into design criteria that can be ranked and prioritized according to their importance in later phases of the regional project.

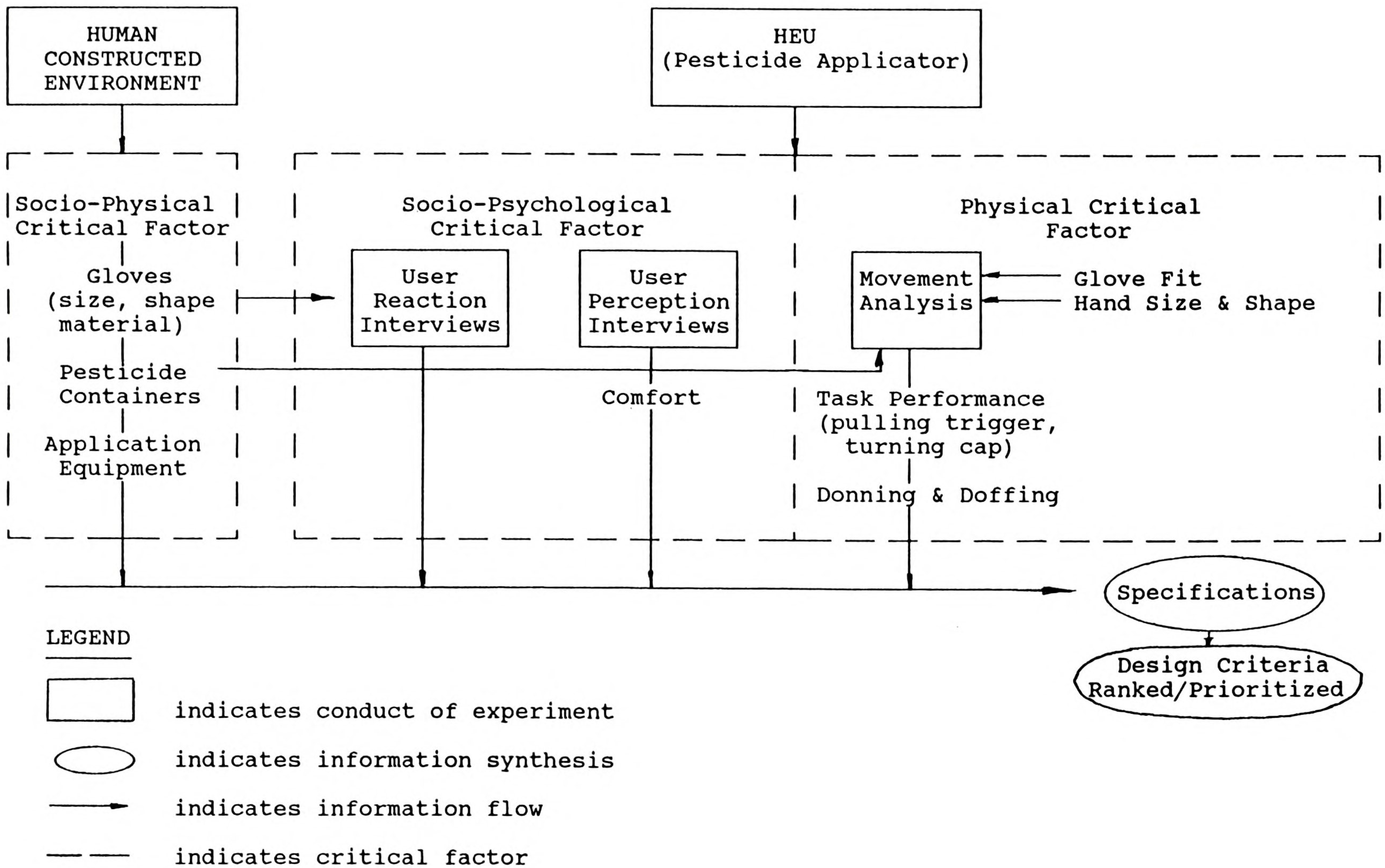


Figure 3: Activity/information interaction flow process for the development of functionally designed protective gloves for the agricultural worker (adapted from Branson, 1982).

LIMITATIONS

Any research design has limitations that are inherent. One limitation of this study was that the subjects for the portion of the study using high speed cinematography were not experienced pesticide applicators but male students at Michigan State University. The effect of not using pesticide applicators for this portion of the study was be minimzed by using typical pesticide containers and equipment. However, one advantage was that the students were familiar with the filming process so their actions were not inhibited.

Another limitation of the study was that the pesticide applicators knew that they were being videotaped. This may have inhibited/altered some of their movements and, thus, may not have given the researchers accurate data on pesticide applicators' process of donning and doffing the pesticide protective gloves. To minimize this effect, a telephoto lens was used on the video camera so the researchers did not need to be as close to the pesticide applicators and, therefore, not as obvious. This effect was also minimized because the workers were videotaped three times as they were working, thus, giving them the opportunity to forget they were being videotaped.

Chapter Four

METHODOLOGY

Because dermal exposure can occur during the use of pesticides, it is recommended that individuals working with pesticides wear gloves to decrease the likelihood of exposure. Gloves, however, are available in a variety of fabrics and styles. This section discusses each of these topics: choice of glove for kinematic analysis, the consistency of glove sizing, different methods of measuring gloves, and the use of high speed cinematography and videotaping for motion analysis.

ANALYSIS OF GLOVES

Choice of Glove

Because the researcher wanted to select gloves for the study that represented current availability, a survey was completed of catalogs from eleven different protective apparel distributors dated from 1987 through 1989. Four of the catalogs did not have dates on them but were believed to be from the same time period. These catalogs carried protective gloves for use with chemicals/pesticides (See Appendix B for listing of catalogs used). The recommendations stated in Chapter 2 were taken into consideration when completing the survey, therefore, no cotton or leather gloves or gloves with linings were counted. Each glove was counted only once as it appeared in each catalog for whichever style and fabric categories it was available. The count was

performed in this manner so that the amount of advertising done for one particular glove type did not affect the count.

The survey found that most manufacturers offered neoprene, rubber and nitrile gloves for use with pesticides (See Table 1). Each of these materials was available in all of the catalogs. Materials that were recommended by researchers, extension specialists, and the government were neoprene and rubber. The glove count showed, however, that more neoprene gloves were available than rubber gloves. The two most common neoprene gloves had curved fingers and shaped palms with one having a 304.8 mm (12") smooth grip and a rolled cuff and the other having an 457.2 mm (18") wet grip and a rolled cuff.

The glove selected for the kinematic portion of this study was made from neoprene because it is recommended for use with pesticides and it appeared to limit the dexterity of the hand the most. The glove was 22 mil thick, was 304.8 mm (12") long, had curved fingers and shaped palms and is available in sizes 9, 10, and 11. The glove's brand and number are Stanzoil N-44, and it was manufactured by Pioneer. This study controlled for the variables of glove design, glove thickness, and glove material.

<u>Consistency of Glove Size</u>

In order to examine the relation of glove size to hand size and the effect on motion, the researcher had to know if standard sizes were available from glove manufacturers. To determine whether or not glove sizes were standard or were not dependent on the style of glove, three different glove styles were measured. Two of each glove size were measured to obtain an average measurement. All of the gloves were

TABLE 1
Survey of Gloves Available in Catalogs
Offering Protective Clothing

GLOVE COUNT (Eleven catalogs between 1987 and 1989 were used for the glove count.)			
STYLE OR DESIGN	RUBBER	NEOPRENE	NITRILE
CURVED FINGERS & SHAPED PALM --10 1/2" wet grip, rolled cuff		1	
--10 1/2" smooth grip, straight cuff		1	
--11" embossed grip, rolled cuff	4	3	
--11" smooth grip, straight cuff	1	1	
--11" smooth grip, rolled cuff	3	3	
--12" smooth grip, rolled cuff	1	1	
--12" wet/embossed grip, rolled cuff		4	
--12 1/2" embossed grip, straight cuff			1
--13" smooth grip, straight cuff	1		
--13" embossed grip, straight cuff	1		
--14" smooth grip, rolled cuff	1	2	
--14" wet grip, rolled cuff		3	
--18" smooth grip, rolled cuff	2		
--18" wet grip, rolled cuff		4	
GLOVES THAT ARE NOT PRESHAPED --13" embossed grip, straight cuff	1		4
--14" embossed grip, straight cuff			2
--15" embossed grip, straight cuff			1
--18" embossed grip, straight cuff			2
TOTALS	15	23	10
Each glove was counted only once as it appeared in each catalog for whichever style and fabric categories it was available. Therefore, the amount of advertising done for one particular style did not affect the count.			

manufactured by Pioneer. Style 1 was a Stansolv brand glove made from Nitrile and was 22 mil thick and 330.2 mm (13") long. Style 2 was a TRIonic brand glove made from a tripolymer and was 19 mil thick and 355.6 mm (14") long. Style 3 was a Stanzoil brand glove made from neoprene and was 22 mil thick and 304.8 mm (12") long. The glove circumference was the measurement taken for comparison (See Table 2). The glove circumference was measured in the same spot as hand circumference was measured (See Appendix A). Each glove was measured three different ways to determine which method was the easiest to execute and to determine if the different methods yielded similar results.

Methods for Measuring Glove: The first method was suggested by Tremblay (1989). It consisted of using a tape measure to measure the glove circumference from the outside and then subtracting the thickness of the glove twice. Secondly, the glove circumference was measured by turning the glove inside out and using a tape measure to get the measurement. The researchers used this method to see if taking the measurement inside the glove would eliminate the need to subtract the glove thickness. Results from this method, however, were the same as for the method suggested by Tremblay (1989) before the glove thickness was subtracted. These results are assumed to be explained because when the glove is turned inside out the inside of the glove becomes the outside of the glove so the measurement taken would actually be the outside of the glove. The differences in the measurements could be due to the accuracy of the measuring instrument.

TABLE 2

Comparison of Glove Measurements by Three Different Methods for Three Styles of Gloves

GLOVE TYPES

ID	BRAND	CATALOG NO.	MATERIAL (THICKNESS)	LENGTH	MANUFACTURER
1	Stansolv	A-15	Nitrile (22 mil)	13"	Pioneer
2	TRIonic	E-194	Tripolymer (19 mil)	14"	Pioneer
3	Stanzoil	N-44	Neoprene (22 mil)	12"	Pioneer

GLOVE MEASURMENTS

SIZE	Tremblay's Method				Inside Out				Calipers			
	RIGHT		LEFT		RIGHT		LEFT		RIGHT		LEFT	
STYLE	MM	IN	MM	IN	MM	IN	MM	IN	MM	IN	MM	IN
SIZE 9												
1	250.82	9.87	250.82	9.88	250.83	9.88	250.83	9.88	237.42	9.35	234.44	9.23
2	241.29	9.50	241.29	9.50	241.30	9.50	241.30	9.50	222.98	8.78	223.10	8.78
3	250.82	9.87	250.82	9.87	250.83	9.88	250.83	9.88	234.82	9.25	227.18	8.94
SIZE 10												
1	260.34	10.25	260.34	10.25	260.35	10.25	260.35	10.25	236.72	9.32	242.82	9.56
2	260.34	10.25	260.34	10.25	260.35	10.25	260.35	10.25	241.92	9.53	242.16	9.53
3	260.34	10.25	260.34	10.25	260.35	10.25	260.35	10.25	238.72	9.40	239.26	9.42
SIZE 11												
1	279.39	11.00	279.39	11.00	279.40	11.00	279.40	11.00	259.72	10.23	261.78	10.31
2	279.39	11.00	279.39	11.00	279.40	11.00	279.40	11.00	265.66	10.46	265.20	10.44
3	279.39	11.00	279.39	11.00	279.40	11.00	279.40	11.00	259.62	10.22	258.98	10.20

The third method of measuring the glove circumference used digital calipers as the measuring device. The measurement for glove circumference was taken by turning the glove partially inside out to the point where the measurement is generally taken. The measurement was then taken by placing the digital calipers inside the glove between the thumb opening and where the openings for the fingers start. Once the measurement was taken, it was doubled to obtain the glove circumference.

The first two methods used for measuring the gloves yielded similar results. The third method, however, yielded values that differed from the other two. The researchers believe this was because it was difficult to measure the glove at the same spot on every glove because of where the measurement was taken. It was also difficult to get accurate measurements using this method because the digital calipers tended to stretch the glove as it was being measured. However, each glove was not stretched an equal amount.

From the measurements taken, the protective gloves seemed to be fairly standard in their sizes. The only discrepancy noted in the measurements was the difference in the size 9 gloves of Style 2. Two possible reasons for these results would be because Style 2 is a different brand of glove than Styles 1 and 3 and is 19 mil thick instead of 22 mil. One would expect, however, that the glove measurements for the size 9 Style 2 glove would be the same as size 9 Styles 1 and 3 gloves because the sizes 10 and 11 of Style 2 glove had the same measurements as the sizes 10 and 11 of Styles 1 and 3 gloves.

KINEMATIC ANALYSIS

Choice of Tasks

Since this study was part of a regional study, it was coordinated with researchers in other states. Researchers at Oklahoma State University, directed by Branson, videotaped pesticide applicators in the summer of 1988 while they completed a number of typical tasks. The filming was completed in the field and a telephoto lens was used to focus on hand movements. Researchers have identified three common tasks to be twisting couplings, opening pesticide containers and donning and doffing gloves. This study attempted to supplement the video data by using the same tasks with high speed cinematography. The tasks that were simulated in this study were (1) a twisting off/on action (i.e. couplings, caps) and (2) pulling the trigger on a hand held spray gun.

Choice of Participants

The participants in the portion of this study which explored the usefulness of high speed cinematography, were three male students from Michigan State University. The participants ranged in age from 21 to 30. The participants all gave their informed consent to participate in the study as required by the University Committee on Human Subjects.

Description of Process for High Speed Cinematography

To achieve accurate measurements with this technique, it was essential that the markers used in the targeting scheme be visible to both cameras. The four measurements that were taken to calculate linear and angular velocities and accelerations of the body segments were time, distance, position, and angles. The conditions examined in

this study were the difference in displacements during each individual's performance of the tasks both with and without gloves.

The filming for this study was done at the Center for the Study of Human Performance at Michigan State University. Two LOCAM cameras were used for the filming and were located so as to have both an anterior and a lateral view allowing each camera a view of the targets. Two cameras were used to provide the two sets of two dimensional positions of each target.

The filming was completed using 16 mm high speed film at 64 fps, a shutter angle of 120 degrees which gave an exposure rate of 1/190 second, and a frame time of 0.0156 second. The first item filmed was the calibration structure. The calibration structure was filmed to define the space in which the targets were being filmed.

Pilot Study

First, a pilot study was completed using one volunteer. Baseline data were collected by marking three targets on the hand and three on the forearm when barehanded and three on the glove cuff and hand when wearing gloves. Before filming the participants performing the actions, a neutral file showing the hand/wrist/forearm not moving was filmed for each participant. All movement of the hand/wrist/forearm is relative to this position; it is considered to be the "zero point." Both conditions also had two targets placed on digits two, three, and four and one target placed on digit five. The participant was filmed untightening and tightening a pesticide container cap and pulling the trigger on a hand held spray gun with and without gloves. The data for the pilot study were evaluated to see if the procedures needed to be

modified. Modifications made were the movement of the forearm targets from the cuff of the glove to the forearm itself, and the removal of the targets placed on the fingers. These targets were removed for two reasons: (1) there was not sufficient room on the fingers to place enough targets to show movement at the joint and (2) not all the finger motion was visible from both cameras.

Final Study

Before the participants were filmed, their hands were measured (See Appendix C). The participants then selected the glove that fit the best. The glove was measured to see how its measurements compared with the paticipant's hand shape and size. Targets were then placed in groups of three (triads) on both the hand and the forearm. As mentioned, the targeting scheme was a modification from the method used in the pilot study. In the pilot study, targets were placed on the glove cuff and did not indicate the turning movement of the forearm inside the cuff. These triads of targets were used to define two rigid bodies in space. Three replications of each task for each of three participants were filmed to assure that the motion was done correctly and to assure that there would be more than one action on the film in case it was damaged. The calibration structure and neutral files were also filmed.

After the filming was completed, data reduction was performed by digitization for one replication of each action for all three participants. "Digitization is the process by which information from the film is electronically gathered" (Ulibarri, 1984, 23). Basically, it involves recording the position of each target in each frame of the

film. An ALTEK rear digitizer with an Eika stop action projector was used for the digitization process. The digitized data were stored on floppy disks via an IBM PC. During the digitizng process, it became evident that the pulling motions while operating the spray gun had minimal movement at the wrist where the targeting scheme was located for both the gloved and ungloved conditions. While there was obvious finger movement, no targets had been placed on the fingers for the reasons stated previously when discussing the pilot study. Therefore, the data for the pulling action was not pursued further and it was decided to examine only the grosser movement at the wrist. Therefore, the data for the pulling action of the spray were eliminated from further analysis.

After digitization was completed, the files that were stored on the floppy disks for tightening/untightening the container cap from both camera views for each participant were combined and converted to ASCII format. After converting the data to ASCII format, it was evident that some of the data was mismatched. Since this study also explored a methodology for quantifying hand action gloved and ungloved, it was determined that only the data that was matched after conversion to ASCII format would be analyzed via the Prime computer located in the Computer Aided Design/Computer Aided Manufacturing lab in the Case Center, College of Engineering at Michigan State University. Direct linear transformations were then performed on the data which yielded three-dimensional data (Walton, 1981). The data were analyzed using existing software (Soutas-Little, 1989) and were then graphed.

VIDEO ANALYSIS

Choice of Participants

Participants used to study the motion involved in donning and doffing protective gloves were pesticide applicators at Michigan State University. Participants were contacted through their supervisors and asked to voluntarily participate. The participants all gave their informed consent to participate in the study as required by the University Committee on Research Involving Human Subjects. The supervisors were interviewed to determine what products applicators were using, the method and frequency of application, type of gloves worn, if any, and problems associated with gloves (See Appendix D). The information from these interviews served as a basis for determining which applicators would be able to be videotaped for this study. The nine participants were males ranging in age from mid-20's to mid-40's. All of the subjects used a variety of different application equipment.

Hand measurements (See Appendix E) were taken for these participants for comparison to glove measurements to determine if the fit influenced method of donning and doffing and to see if the gloves were fitting pesticide applicators' hands.

In order to meet the second objective, which was to study the motion involved in donning and doffing protective gloves and factors influencing it in order to identify the mechanism of internal glove contamination, a videotape was made of nine particpants donning and doffing their gloves while they were working. A telephoto lens was used so that only the particpant's hands were videotaped. The

participants were each videotaped three times while they were donning and doffing their gloves to see if there was continuity in each individual's movements while completing this task.

Gloves worn during the videotaping were made from nitrile-latex, butyl rubber or vinyl. Nitrile-latex and butyl rubber were chosen because both are recommended for use with certain pesticides; vinyl gloves were also videotaped because they were found to be worn by Michigan State University pesticide applicators. A record was kept of the size, thickness, style, manufacturer, and fiber content of the gloves worn by each subject. A record was also kept of the participant's hand size and their choice of the glove size that they felt "fit the best."

While viewing the videotape, the researchers recorded the different techniques that the participants used to don and doff their gloves, i.e. order of steps and details such as, where they grasped the glove to remove it. This information was considered in relation to hand measurements. Responses from the interviews were summarized in frequency tables and the hand-glove measurements were graphed and studied in relation to the video tape.

Chapter Five

FINDINGS

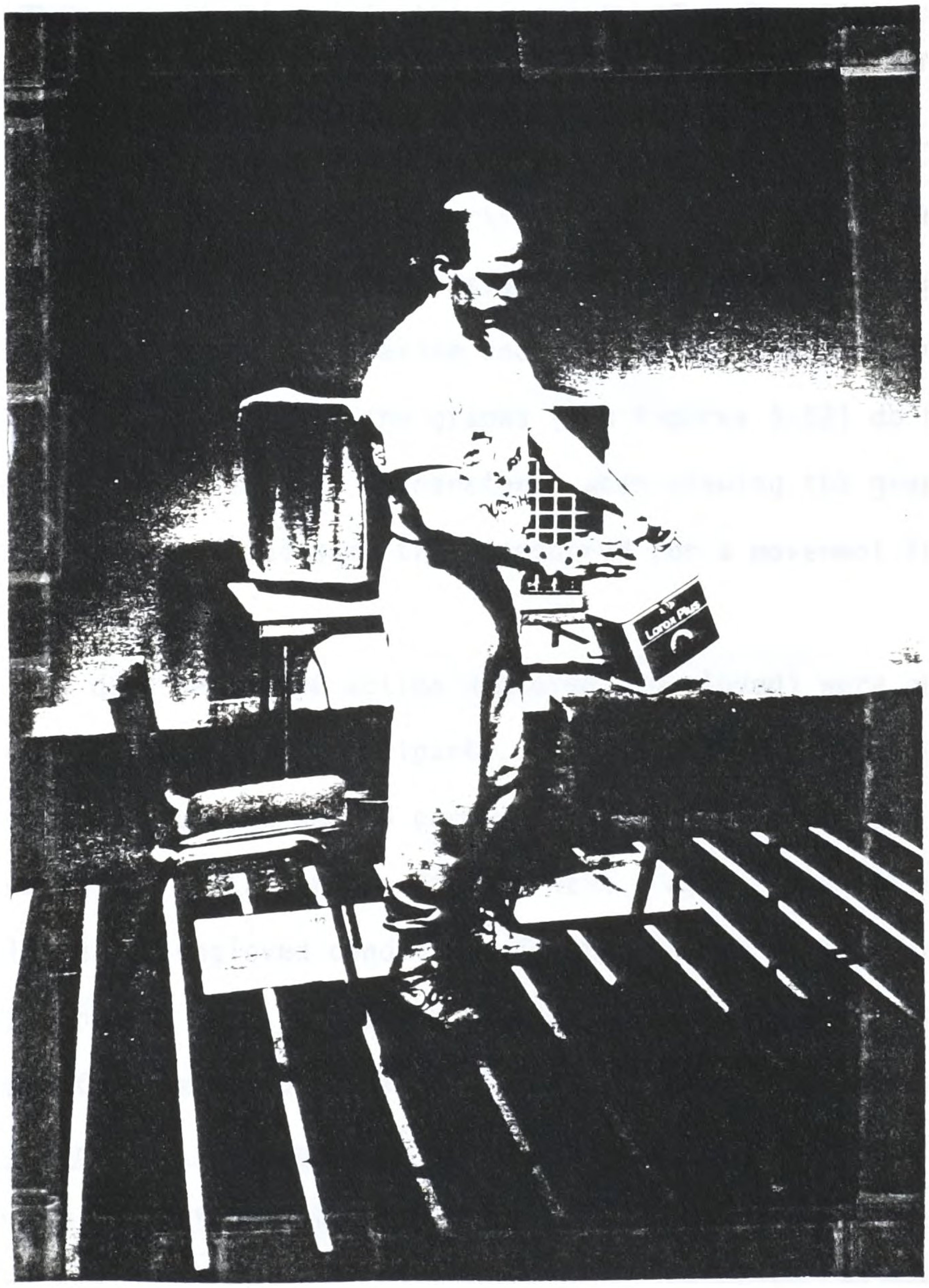
Kinematic Findings

Research Question: Can differences in hand motions involving tightening and untightening container caps be differentiated between gloved and ungloved conditions by utilizing three-dimensional kinematic techniques?

Three dimensional data were obtained via direct linear transformations from the two sets of two-dimensional digitized data for the action of tightening and untightening a pesticide container cap. The starting position for the action is shown in Figure 4. From these transformations, three-dimensional displacements were obtained. The data were graphed and are found in Figures 5 through 22. Shown on the graphs were the variations of angles for abduction/adduction, supination/pronation, and extension/flexion for both the ungloved and gloved conditions. Three-dimensional data for the tightening/untightening actions were graphed for the changes in angles of every two frames. Each graph represents one trial. On the graphs, the frames are located on the horizontal axis, and the degrees are located on the vertical axis.

The number of frames shown for each action indicated how fast/slow the participant completed the action. Therefore, the number of frames will not be consistent across trials or participants. How fast/slow an action was completed affected the spread of the graph. Variations in the spreads of the graphs also occurred because the actions were not

Figure 4. The Starting Position for the Action of Tightening/ Untightening a Container Cap



performed identically by each participant. Each participant was shown how to place their hand on the container cap and was instructed to use wrist motion, not arm or finger motion, to tighten/untighten the container cap. When viewing the film, however, some arm movement was visible. This caused changes in the movements of each action. Spreads of the graphs also differed because each participant's hand was not positioned identically on the container cap. Because the positioning was not identical for each action/participant, differences in movements were evident. Therefore, it is necessary to ignore the starting position in relation to the baseline and instead consider the overall spread of the graphs. All of the graphs (See Figures 5-22) do tend to follow the same basic spread. Therefore, when viewing the graphs it is important to see if the same trend occurred for a movement for all the participants.

Complete data sets (one action ungloved and gloved) were obtained for only one of the three participants. A set of data for untightening the container cap for the second participant was obtained. The data for tightening the container cap did not have a comparable set of data for the gloved and ungloved conditions for the second participant due to digitization and post-processing problems. No data were examined and analyzed for the third participant for the above stated reasons.

<u>Tightening the Container Cap</u>: The data graphed for tightening a container cap by participant one are shown in Figures 5-10. When the participant was ungloved, the total angular changes were 102 degrees for abduction/adduction, 41 degrees for supination/pronation, and 20 degrees for extension/flexion. These angular changes illustrated that

Figure 5. The Variation of Angles for Abduction/Adduction for the Ungloved Condition when Tightening a Container Cap--Participant One.

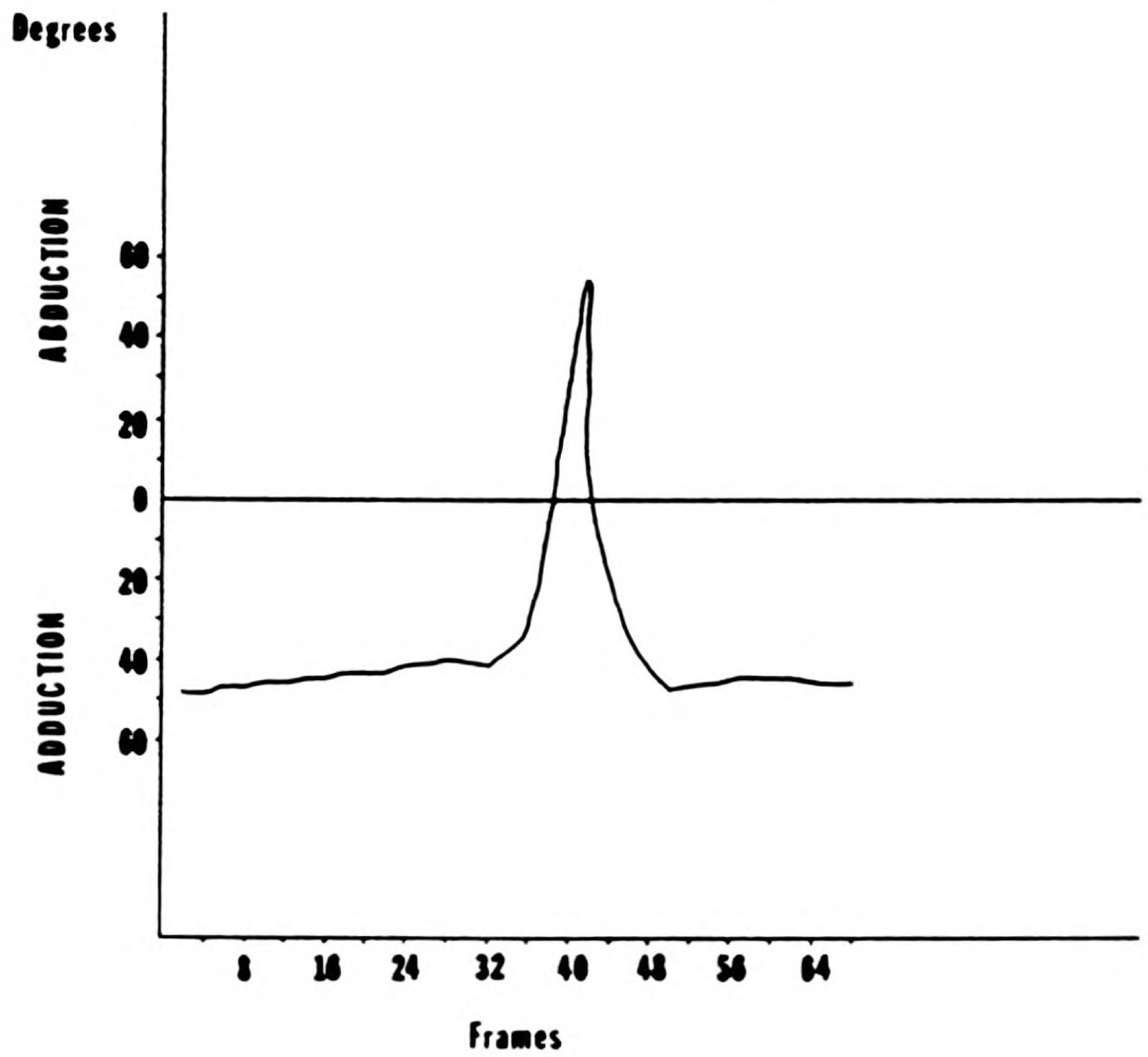


Figure 6. The Variation of Angles for Abduction/Adduction for the Gloved Condition when Tightening a Container Cap--Participant One.

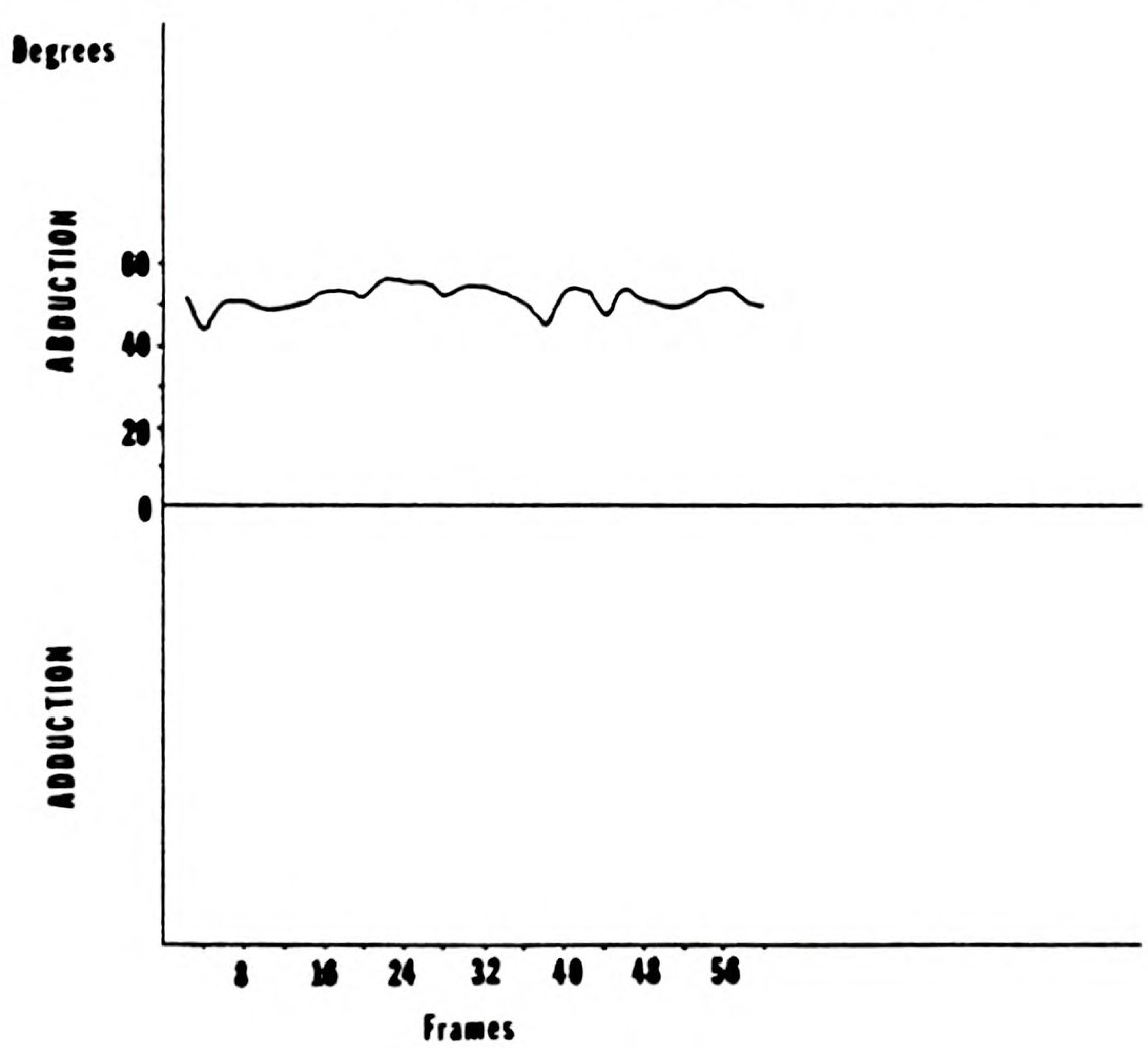


Figure 7. The Variation of Angles for Supination/Pronation for the Ungloved Condition when Tightening a Container Cap--Participant One.

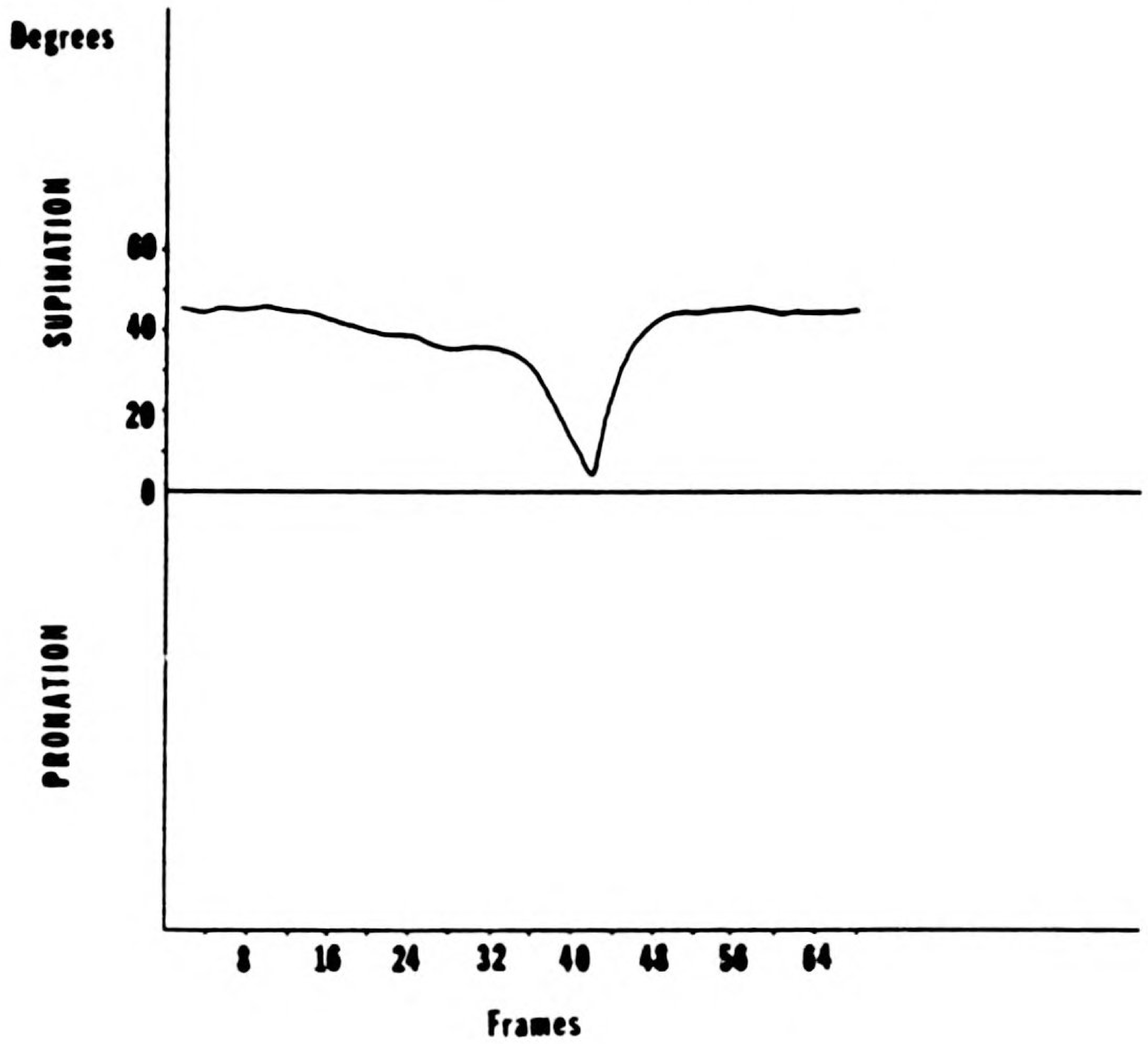


Figure 8. The Variation of Angles for Supination/Pronation for the Gloved Condition when Tightening a Container Cap--Participant One.

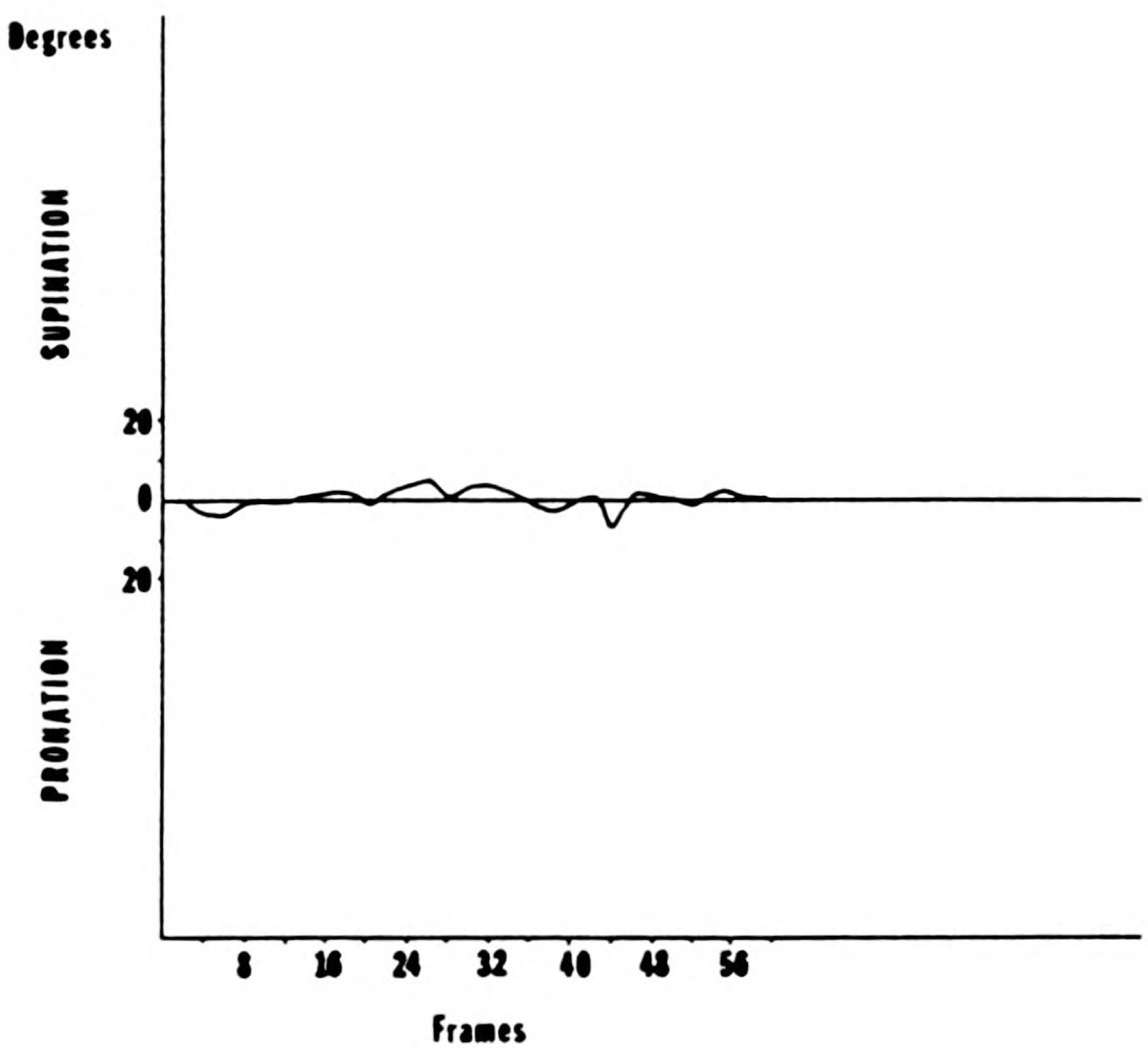


Figure 9. The Variation of Angles for Extension/Flexion for the Ungloved Condition when Tightening a Container Cap--Participant One.

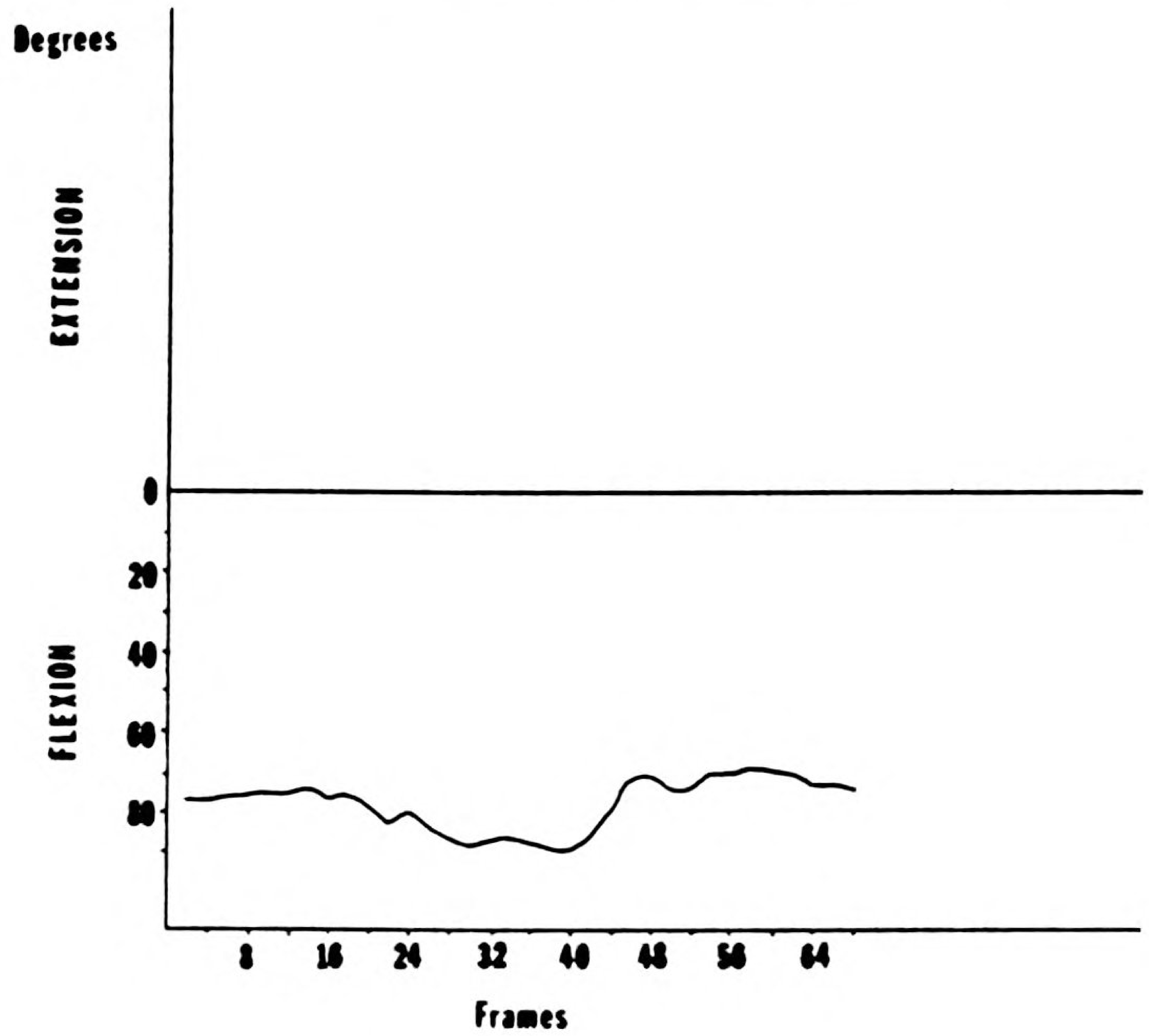


Figure 10. The Variation of Angles for Extension/Flexion for the Gloved Condition when Tightening a Container Cap--Participant One.

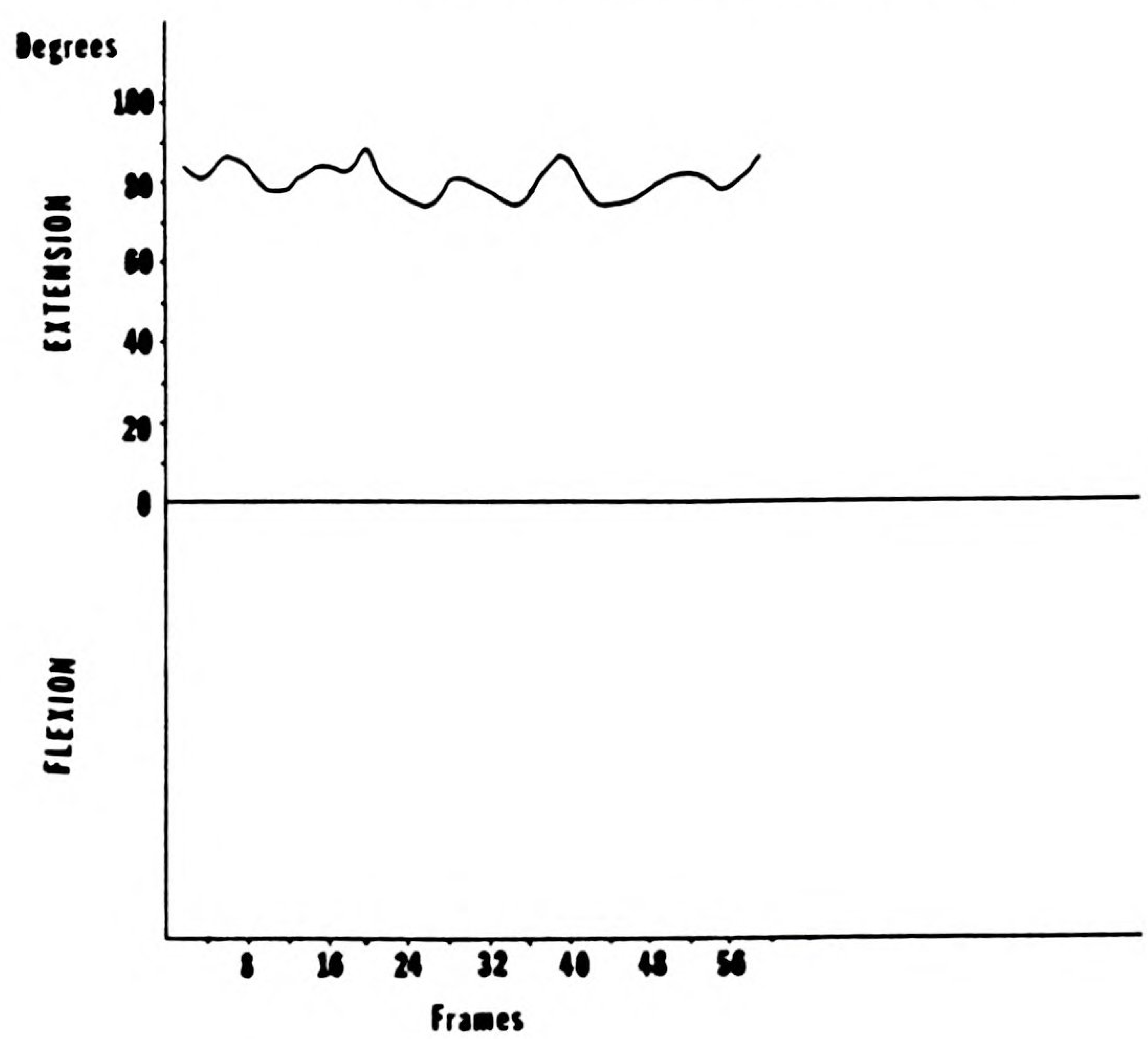


Figure 11. The Variation of Angles for Abduction/Adduction for the Ungloved Condition when Untightening a Container Cap--Participant One.

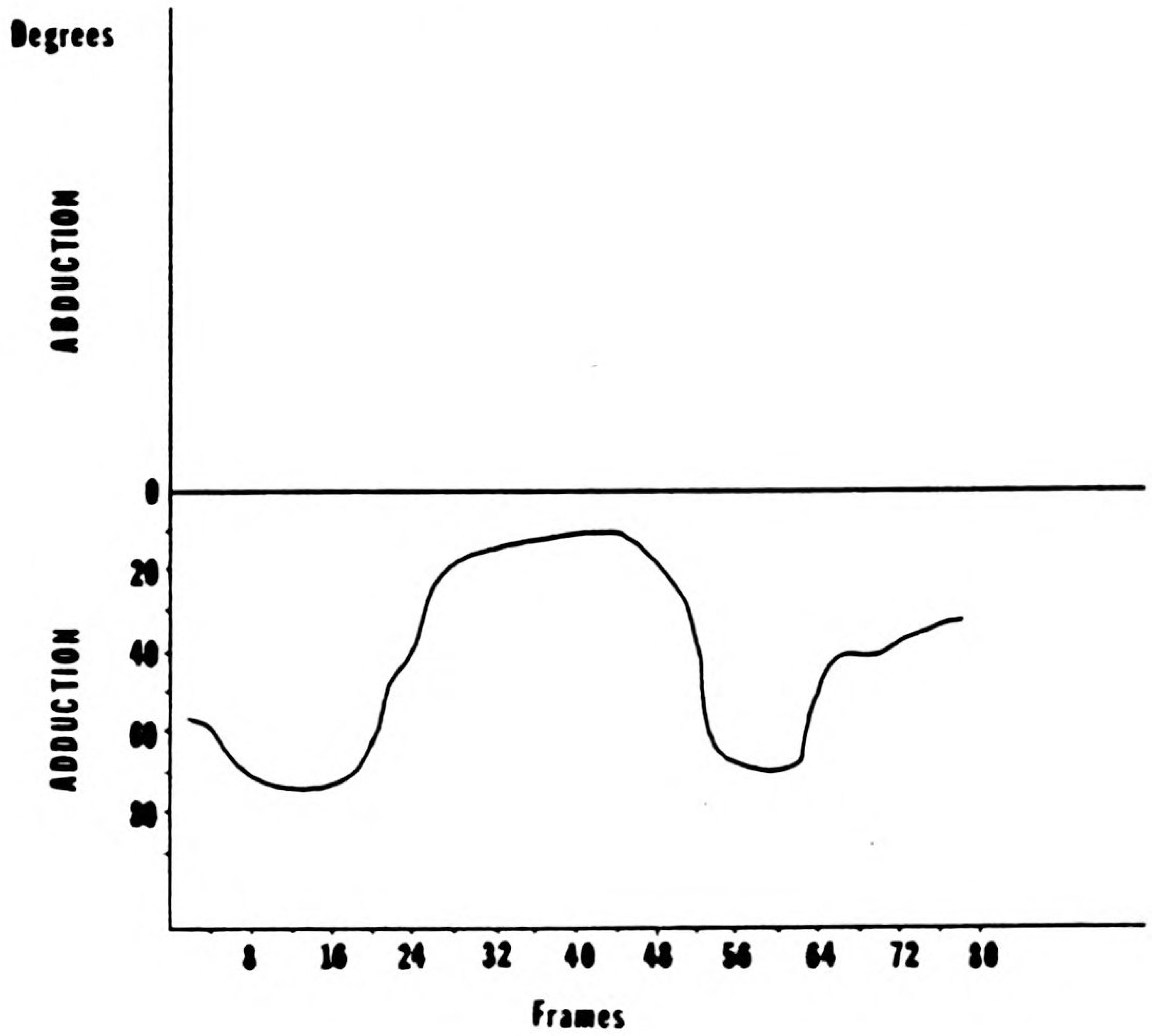


Figure 12. The Variation of Angles for Abduction/Adduction for the Gloved Condition when Untightening a Container Cap--Participant One.

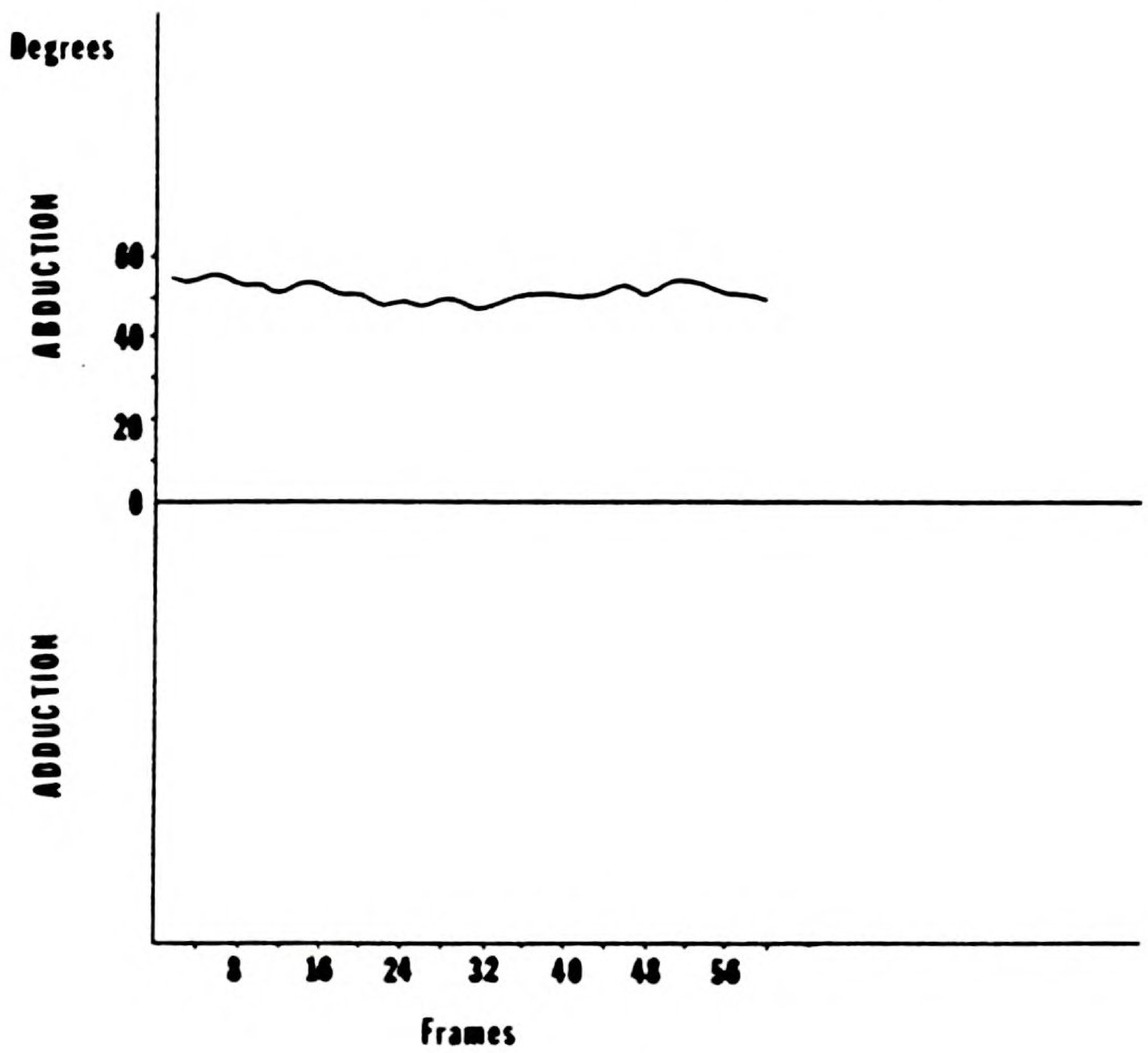


Figure 13. The Variation of Angles for Supination/Pronation for the Ungloved Condition when Untightening a Container Cap--Participant One.

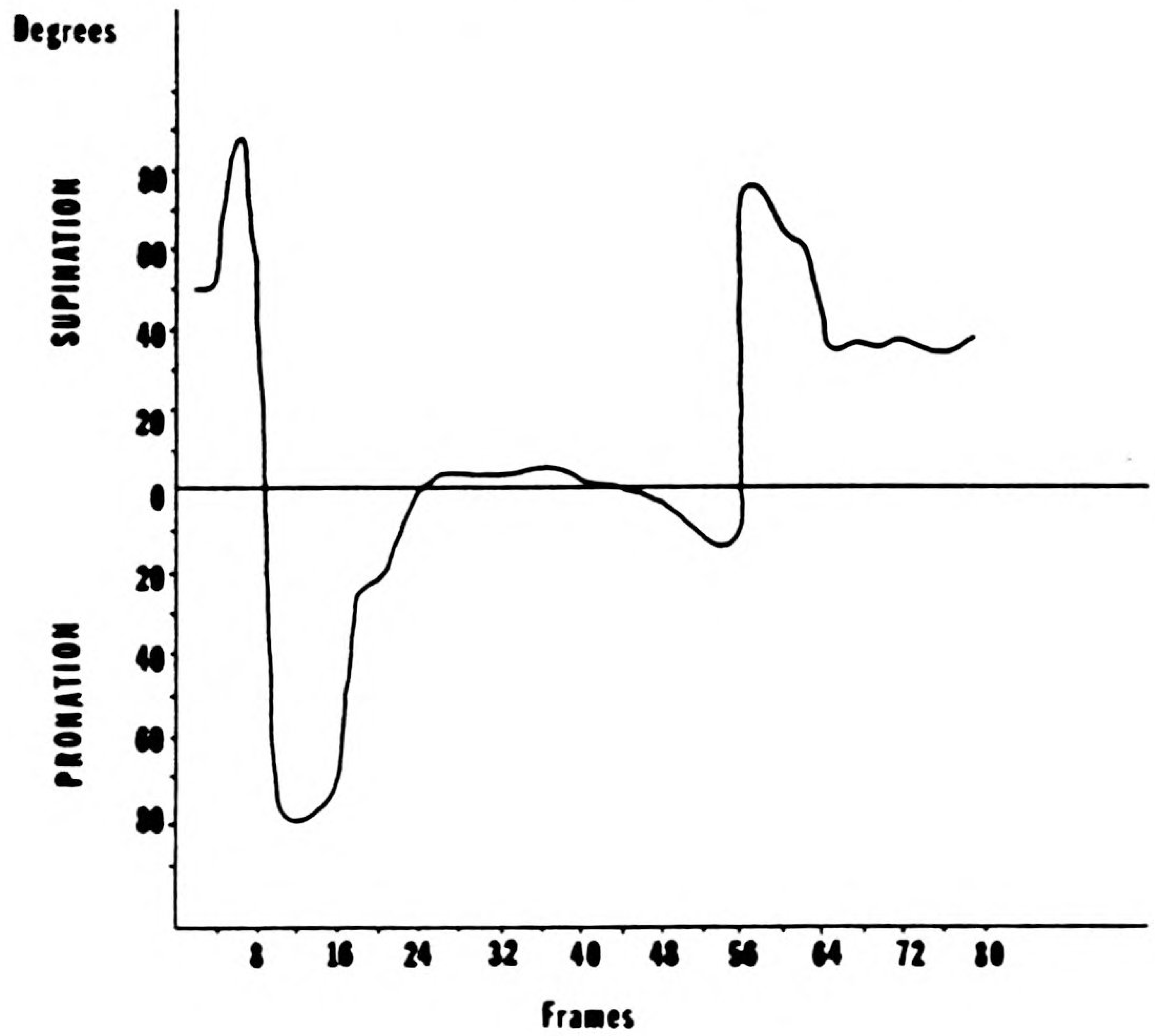


Figure 14. The Variation of Angles for Supination/Pronation for the Gloved Condition when Untightening a Container Cap--Participant One.

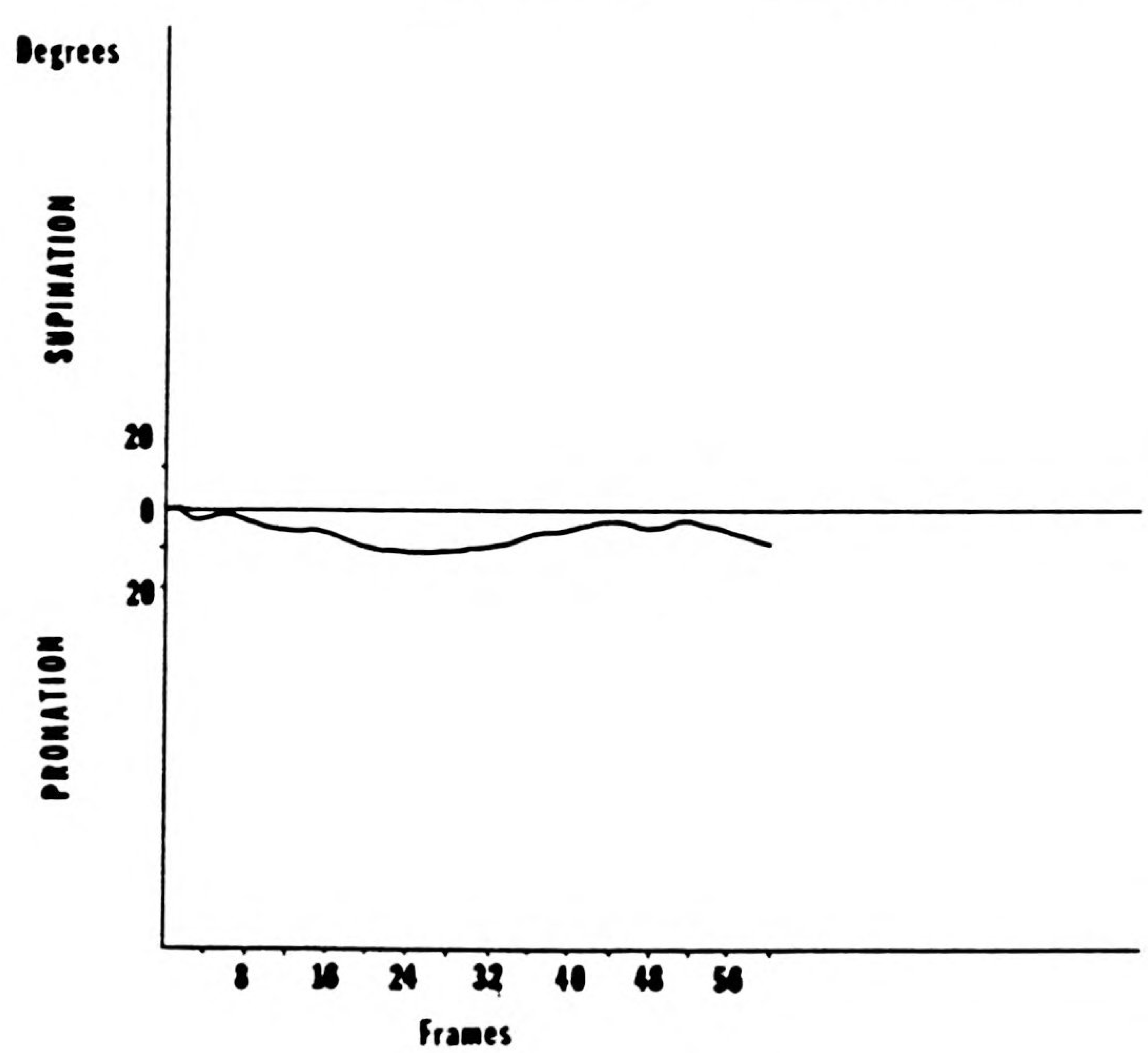


Figure 15. The Variation of Angles for Extension/Flexion for the Ungloved Condition when Untightening a Container Cap--Participant One.

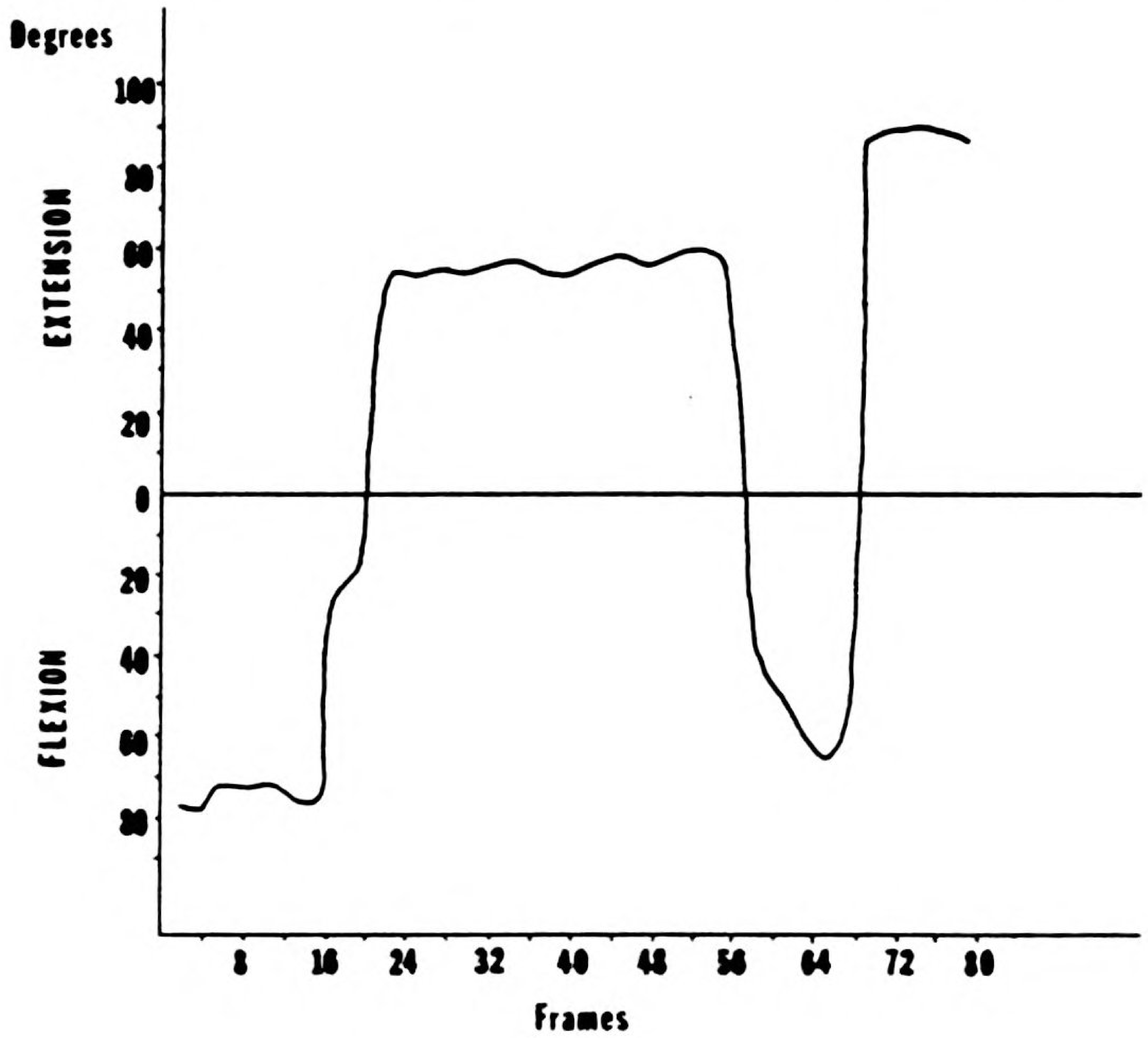


Figure 16. The Variation of Angles for Extension/Flexion for the Gloved Condition when Untightening a Container Cap--Participant One.

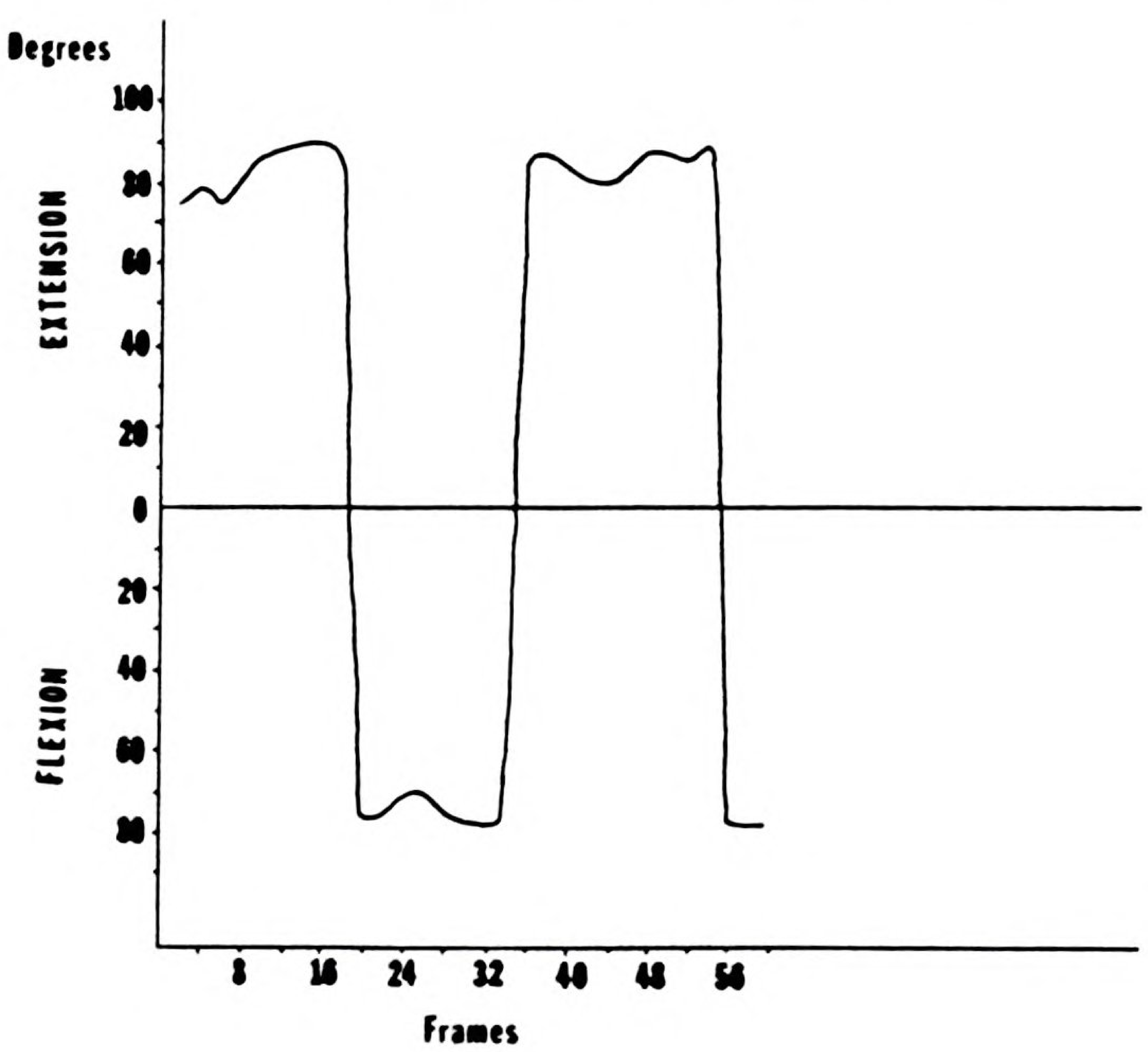


Figure 17. The Variation of Angles for Abduction/Adduction for the Ungloved Condition when Untightening a Container Cap--Participant Two.

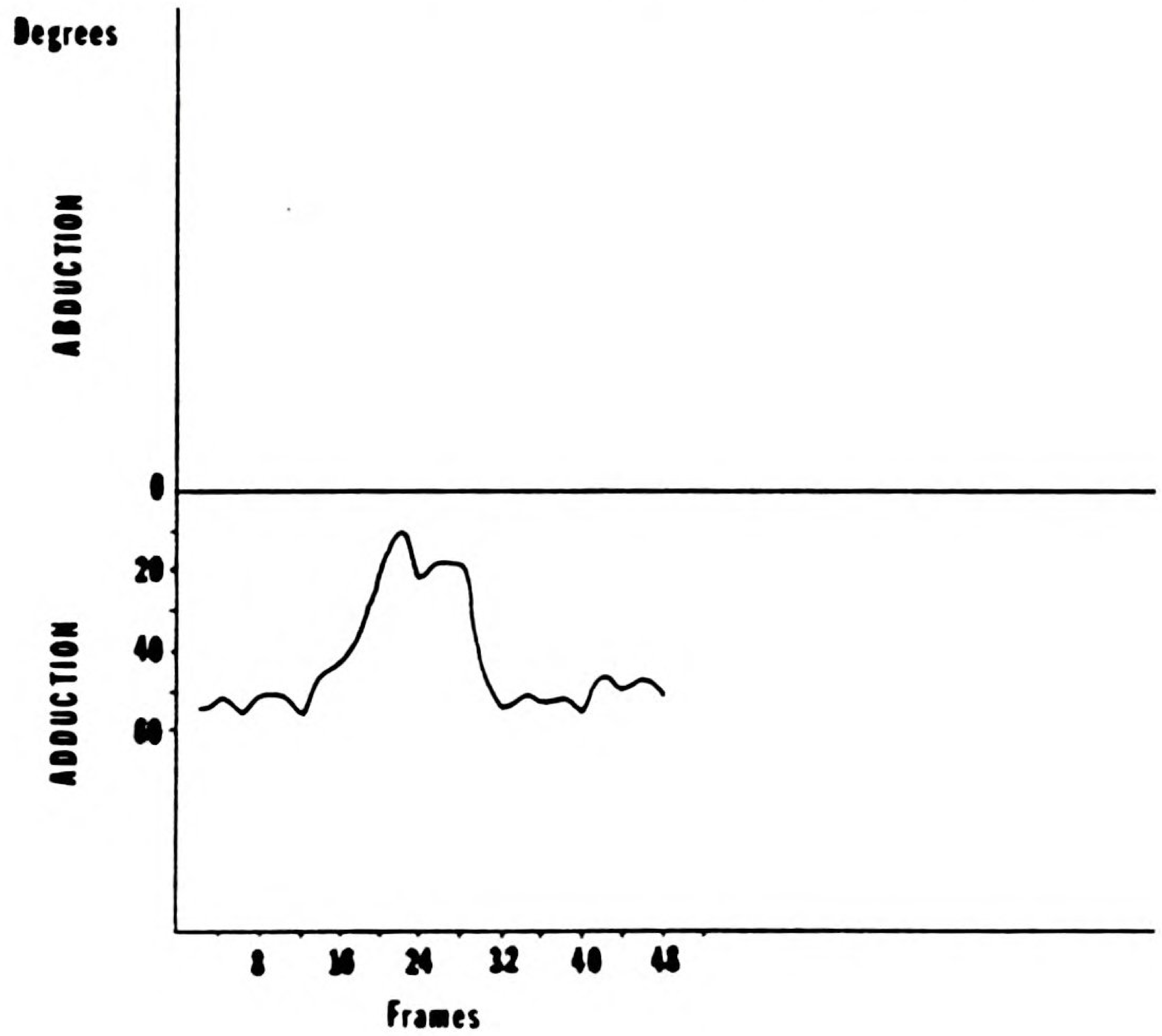


Figure 18. The Variation of Angles for Abduction/Adduction for the Gloved Condition when Untightening a Container Cap--Participant Two.

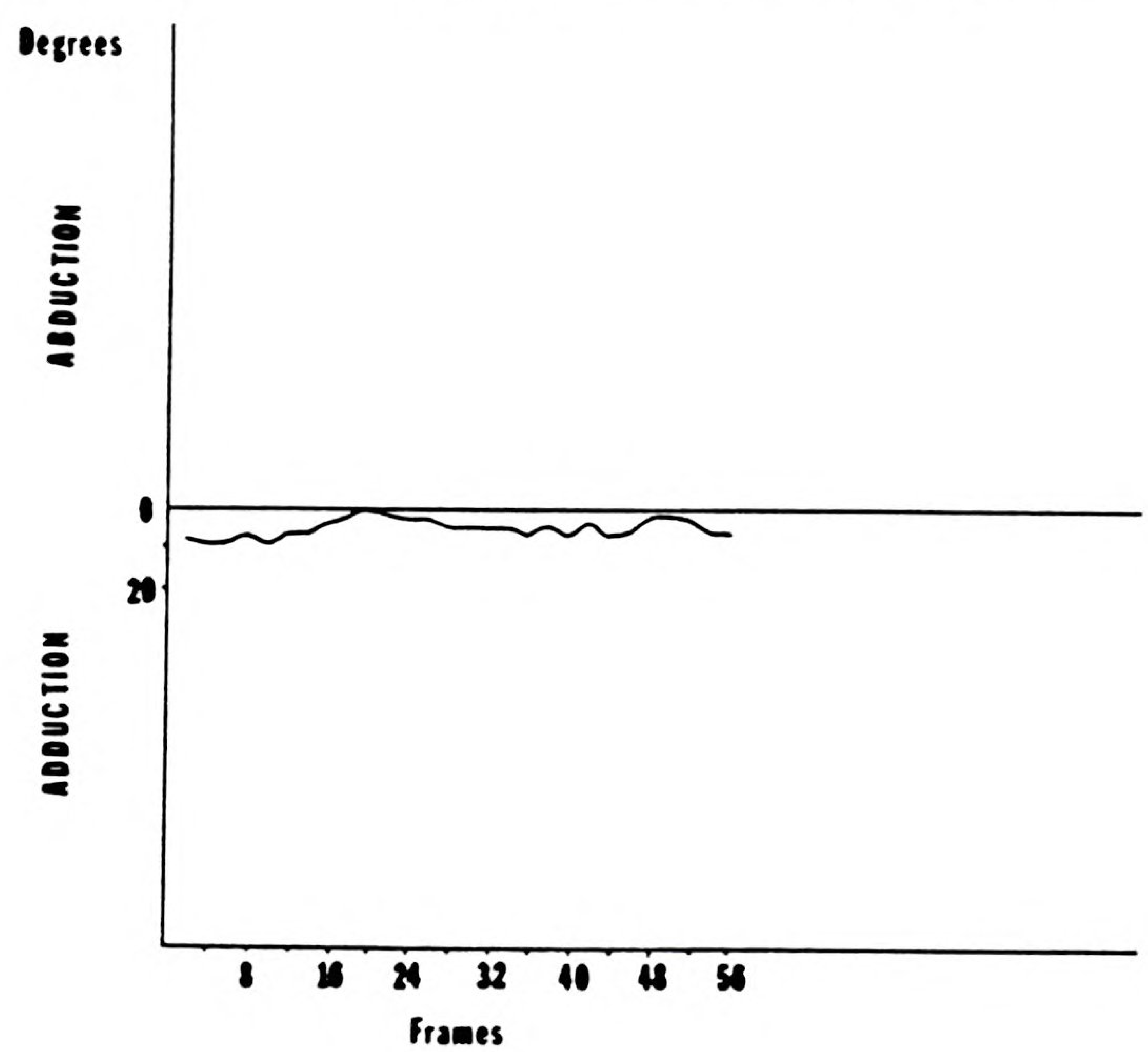


Figure 19. The Variation of Angles for Supination/Pronation for the Ungloved Condition when Untightening a Container Cap--Participant Two.

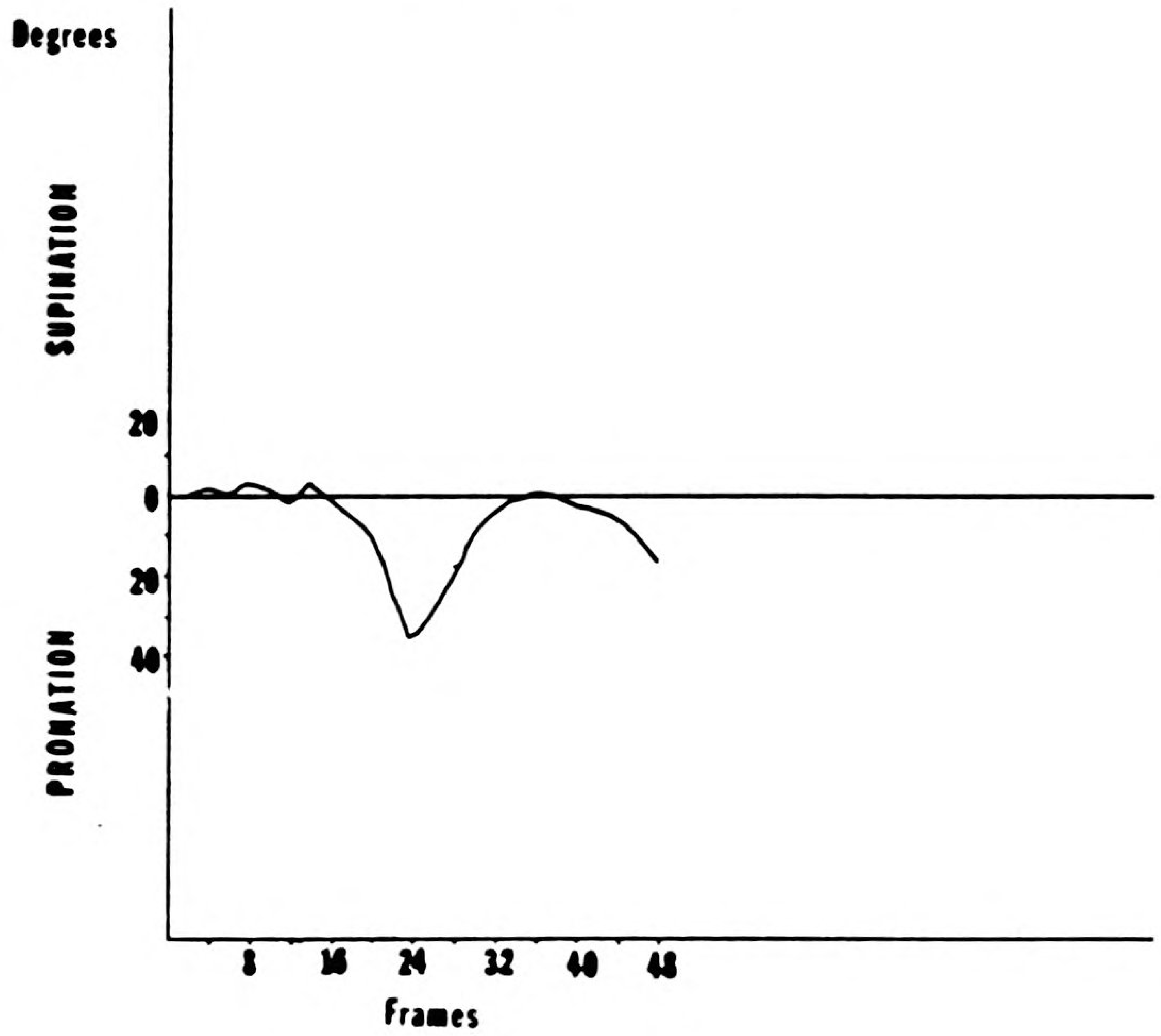


Figure 20. The Variation of Angles for Supination/Pronation for the Gloved Condition when Untightening a Container Cap--Participant Two.

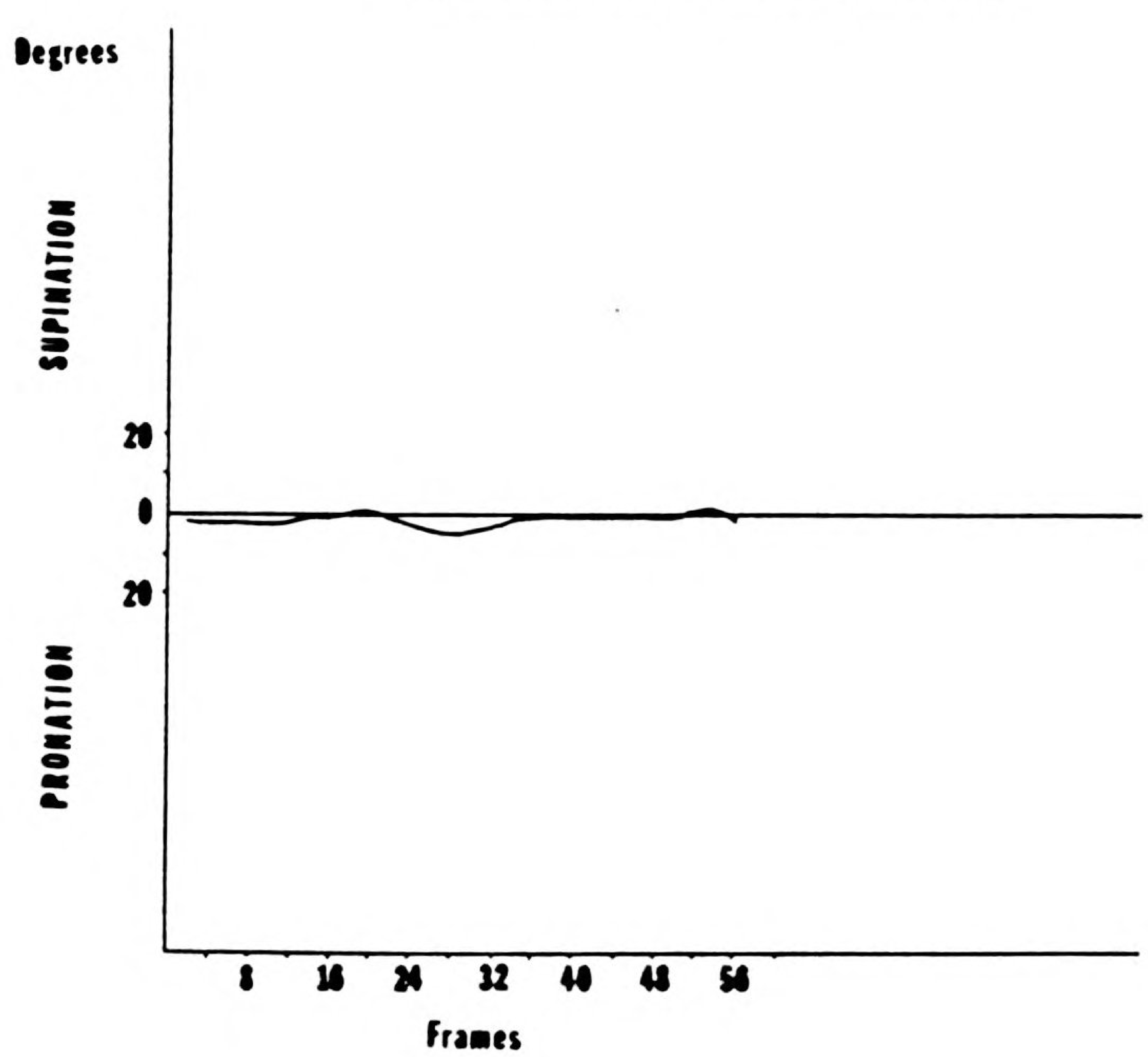


Figure 21. The Variation of Angles for Extension/Flexion for the Ungloved Condition when Untightening a Container Cap--Participant Two.

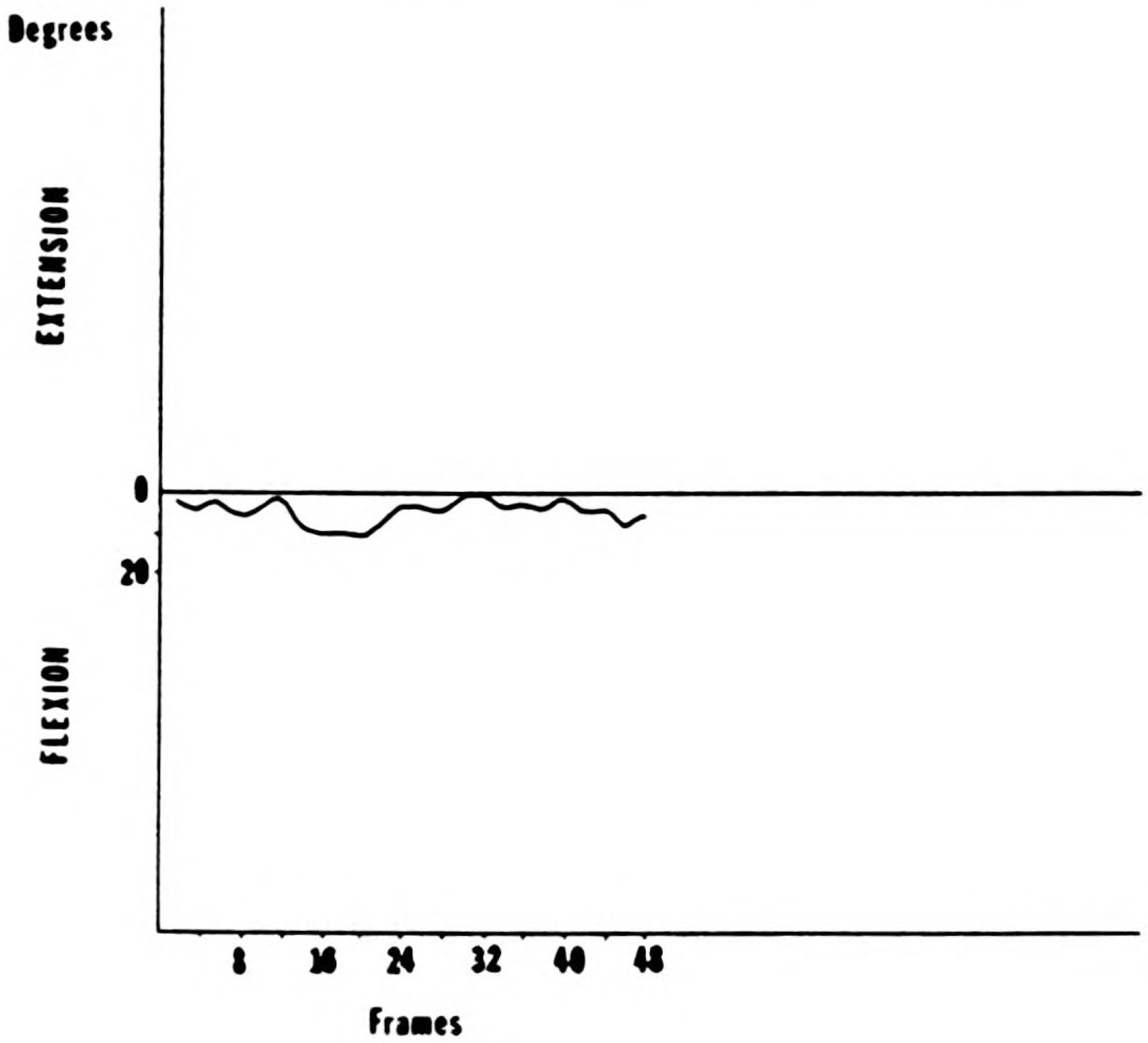
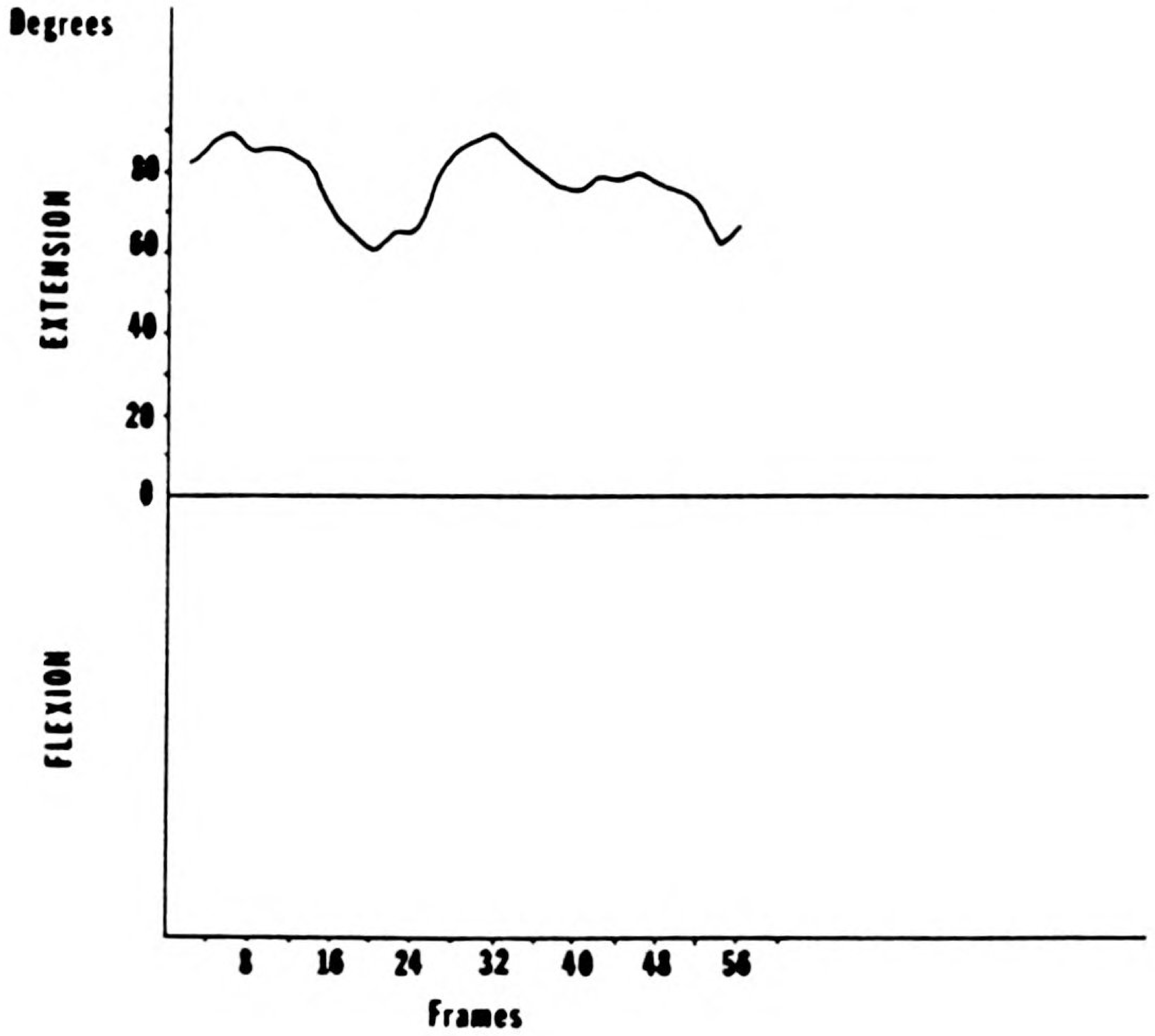


Figure 22. The Variation of Angles for Extension/Flexion for the Gloved Condition when Untightening a Container Cap--Participant Two.



the primary movement involved in tightening a container cap was abduction/adduction which would be combined with supination/pronation, respectively. Some extension/flexion was also found. In the gloved condition, the total angular changes were 14 degrees for abduction/adduction, 12 degrees for supination/pronation, and 15 degrees for extension/flexion. In the gloved condition, extension/flexion were found to be the primary movements associated with tightening the container cap due to the starting position. When wearing the gloves, a decrease in magnitudes were evident for abduction/adduction and supination/pronation. Minimal differences were evident for extension/flexion.

Untightening the Container Cap: The data graphed for untightening a container cap for participant one can be found in Figures 11-16. When the participant was ungloved, the total angular changes were 188 degrees for supination/pronation, 167 degrees for extension/flexion, and 66 degrees for abduction/adduction. These angular changes indicated that the primary movement involved in untightening a container cap was supination/pronation which was due to the position of the container and would be combined with abduction/adduction respectively. Extension/flexion and some abduction/adduction actions were also found. These data were then graphed for each condition. In the gloved condition, total angular changes were found to be 11 degrees for supination/pronation, 167 degrees for extension/flexion, and seven degrees for abduction/adduction. In the gloved condition, extension/flexion were found to be the primary movements associated with untightening a container cap. When wearing gloves for this

action, a decrease in magnitudes was also evident. Once again, the motion of supination/pronation and abduction/adduction decreased.

The data graphed for untightening a container cap for participant two can be found in Figures 17-22. When the participant was ungloved, the total angular changes were 45 dgrees for abduction/adduction, 38 degrees for supination/pronation, and nine degrees for extension flexion. These angular changes show that the primary movement involved in untightening a container cap was abduction/adduction which would be combined with pronation/supination respectively. Some extension/flexion was also evident. In the gloved condition, the total angular changes were nine degrees for abduction/adduction, five degrees for supination/pronation, and 28 degrees for extension/flexion. In the gloved conditon, extension/flexion were once again found to be the primary movements associated with untightening a container cap. A decrease in magnitudes was also evident for this participant when wearing gloves. The magnitudes which decreased were abduction/adduction and supination/pronation.

<u>Summary</u>: The wearing of gloves appeared to decrease the kinematic motion involved in tightening/untightening a container cap. The glove especially appeared to decrease the amount of supination/pronation and abduction/adduction ranges that the hand was able to complete while tightening/untightening a container cap. This could have been attributed to either of the following reasons, either singular or in combination: the glove was ill-fitted (the participants did select the best fitting glove) and was not flexible and thin enough to allow the participant to complete the motion similar to the ungloved condition,

the glove moved differently than the hand, or the targeted skin moved when the bone the hand/wrist/forearm did not. The masking of the motion when the targeted skin moves and the boney landmark does not has been labeled soft tissue movement in biomechanical studies. The last two reasons reasons would give false readings of movement. these findings indicate that it is possible to measure the differences occuring in kinemtaic motion between gloved and ungloved conditions when completing typical tasks. Further study is indicated for glove design and material.

<u>Interview Findings</u>

Research Question: What types of hand protection, if any, do selected campus pesticide applicators use?

Interviews conducted with nine individuals from Michigan State University who apply pesticides or supervise others in the application of pesticides, provided the researchers with information about the use of protective gloves by campus applicators. The individuals interviewed represented these campus units: the Botany and Plant Pathology Research Center, Crop and Soil Science Department, Entomology Department, Grounds Maintenance for the Golf Course, Hancock Turfgrass Research Center, and the Horticultural Research Center. The gloves that these individuals identified as being used in their units (See Appendix D) were made from neoprene, nitrile latex, and vinyl. The most commonly used "protective" glove was the thin (12 mil) disposable vinyl utility glove. The individuals said that they or their employees used this glove because it allowed them a greater level of dexterity than the heavier recommended glove.

Research Question: What problems do pesticide applicators identify with respect to hand protection?

One of the main problems encountered with the vinyl utility gloves was how hot and sweaty the hands get while wearing them in the summer. One individual stated that he accumulates approximately 20 to 30 ml of sweat in the fingertips of the gloves while wearing them. Another individual expressed concern about the level of sweat that built up inside the gloves because he thought the sweat might roll down the hand and out of the glove if too much sweat built up inside the gloves. The amount of sweat build-up inside the gloves also made it difficult for the gloves to be removed. All of the individuals who wore the vinyl utility gloves said they had to peel the glove off from their hand by grasping it at the cuff and pulling. In cold weather, however, the vinyl utility gloves were said to be extremely cold.

The other major problem with the vinyl utility gloves was that the area of the glove, the fingertips and palm, that had the most contact with the equipment tended to break and rip. Others also mentioned that the area between the thumb and index finger broke and ripped. Two other problems mentioned were fit and the fact that the gloves became extremely slippery if any oil was spilled on them.

Those individuals who use the neoprene, rubber, and nitrile latex gloves also complained that their hands became hot and sweaty while wearing the gloves. The main problem noted about the neoprene glove was that it severely limited the applicator's dexteriy and tactile sensation.

Hand Measurements in Relation to Other Hand Data

Research Question: What is the relationship between pesticide applicators' hand measurements and (a) other hand data?

The hand dimensions for the participants of this study were compared with the hand dimensions for Tremblay's participants (1989, p. 121-9), Alberta agricultural workers, to determine if the participants for this study were representative of a larger sample. Even though the sample size for this study was small the means for the following measurements fell between the 55 and 70th percentile rank of Alberta's study: maximum spread, hand length, finger length (digits two-five), hand circumference, and hand breadth (See Table 3). Although the remaining measurements were within the range of those found in Alberta, they ranged between the 5 and 35th percentile rank with the exception of finger tip to elbow (See Table 3). This indicates that the participants in this study had hands that were less thick than those from Alberta.

Hand Measurements in Relation to Glove Size

Research Question: What is the relationship between pesticide applicators' hand measurements and (b) glove size?

To determine how the participant's hand size and shape related to the nitrile and neoprene gloves, these measurements were compared: finger and thumb length (See Table 4, Figures 23a-23e), finger and thumb diameter (See Table 5, Figures 24a-24e), and hand circumference (See Table 6, Figures 25a-25b). For the size nine nitrile glove, it was found that the participant's measurements for finger & thumb length (See Figure 23a), finger & thumb diameter (See Figure 24a), and hand circumference (See Figure 25a) were always smaller than the glove

Table 3. Mean MSU Hand Measurements Measured in MM and Corresponding Percentile Value Based on Alberta Sample of Farmers

	Mean Measurements for MSU subjects	Percentile Values
FINGER TIP TO ELBOW	444.76	3%
MAXIMUM SPREAD	225.95	60%
HAND LENGTH	199.99	60%
FINGER & THUMB LENGTH Digit One	64.99	15%
Digit Two	78.38	70%
Digit Three	85.35	60%
Digit Four	78.93	55%
Digit Five	64.47	60%
HAND CIRCUMFERENCE	230.37	65%
HAND BREADTH	111.34	70%
HAND THICKNESS	49.81	30%
FIST CIRCUMFERENCE	293.56	15%
FINGER & THUMB DIAMETER Digit One	23.48	10%
Digit Two	21.87	10%
Digit Three	21.72	10%
Digit Four	20.11	5%
Digit Five	18.22	5%
GRIP DIAMETER Outside	89.99	35%
Inside	44.34	10%

Table 4
Differences Between Glove and Hand Measurements
for Finger & Thumb Length

DIGIT #	Glove Diameter		Finger & Thumb Diameter		Difference		Percentage of Hand Measurement of Glove Measurement
	IN	MM	IN	MM	IN	MM	
NITRILE, SIZE 9							
Digit 1	69.63	2.74	59.33	2.34	10.30	0.40	14.790%
Digit 2	74.39	2.93	69.31	2.73	5.08	0.20	6.632%
Digit 3	79.16	3.12	76.56	3.01	2.60	0.11	3.278%
Digit 4	72.81	2.87	69.48	2.74	3.33	0.13	4.567%
Digit 5	56.93	2.24	55.72	2.19	1.21	0.05	2.125%
NEOPRENE, SIZE 9							
Digit 1	69.85	2.75	59.33	2.34	6.01	0.41	8.604%
Digit 2	76.20	3.00	69.31	2.73	1.83	0.27	2.402%
Digit 3	84.14	3.31	76.56	3.01	3.39	0.30	4.206%
Digit 4	82.55	3.25	69.48	2.74	7.57	0.51	9.170%
Digit 5	69.85	2.75	55.72	2.19	11.19	0.56	16.020%
NITRILE, SIZE 10							
Digit 1	76.20	3.00	72.20	2.84	4.01	0.16	5.256%
Digit 2	80.96	3.19	80.73	3.18	0.23	0.01	2.872%
Digit 3	95.25	3.75	87.91	3.46	15.23	0.29	7.706%
Digit 4	92.08	3.63	80.88	3.18	11.20	0.45	12.100%
Digit 5	73.03	2.88	66.95	2.64	6.08	0.24	8.326%
NITRILE, SIZE 11							
Digit 1	79.16	3.12	64.87	2.55	14.28	0.57	18.044%
Digit 2	79.16	3.12	82.09	3.23	-2.93	-.11	-3.705%
Digit 3	85.51	3.35	87.66	3.45	-2.15	-.10	-2.514%
Digit 4	82.33	3.24	81.80	3.22	0.53	0.02	0.641%
Digit 5	69.63	2.74	67.37	2.65	2.26	0.09	3.235%
NEOPRENE, SIZE 11							
Digit 1	76.20	3.00	72.20	2.84	4.01	0.16	5.256%
Digit 2	80.96	3.19	80.73	3.18	0.23	0.01	2.872%
Digit 3	95.25	3.75	87.91	3.46	7.34	0.29	7.706%
Digit 4	92.08	3.63	80.88	3.18	11.20	0.45	12.159%
Digit 5	73.03	2.88	66.95	2.64	6.08	0.24	8.326%

FIGURES 23a-23e. COMPARISON OF HAND & GLOVE MEASUREMENTS FOR FINGER & THUMB LENGTH

FIGURE 23a
NITRILE--SIZE 9, N=1

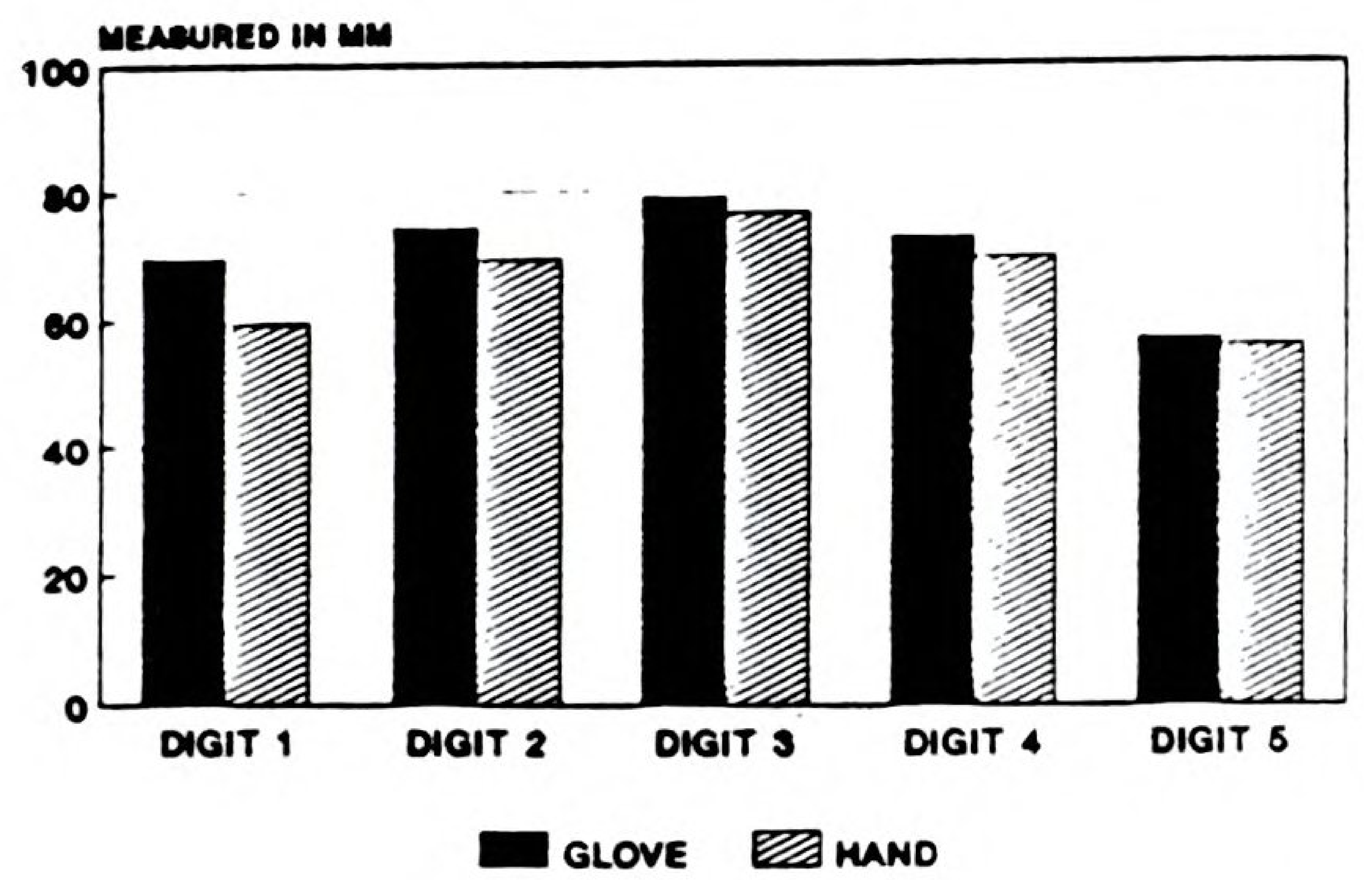


FIGURE 23b
NEOPRENE--SIZE 9, N=1

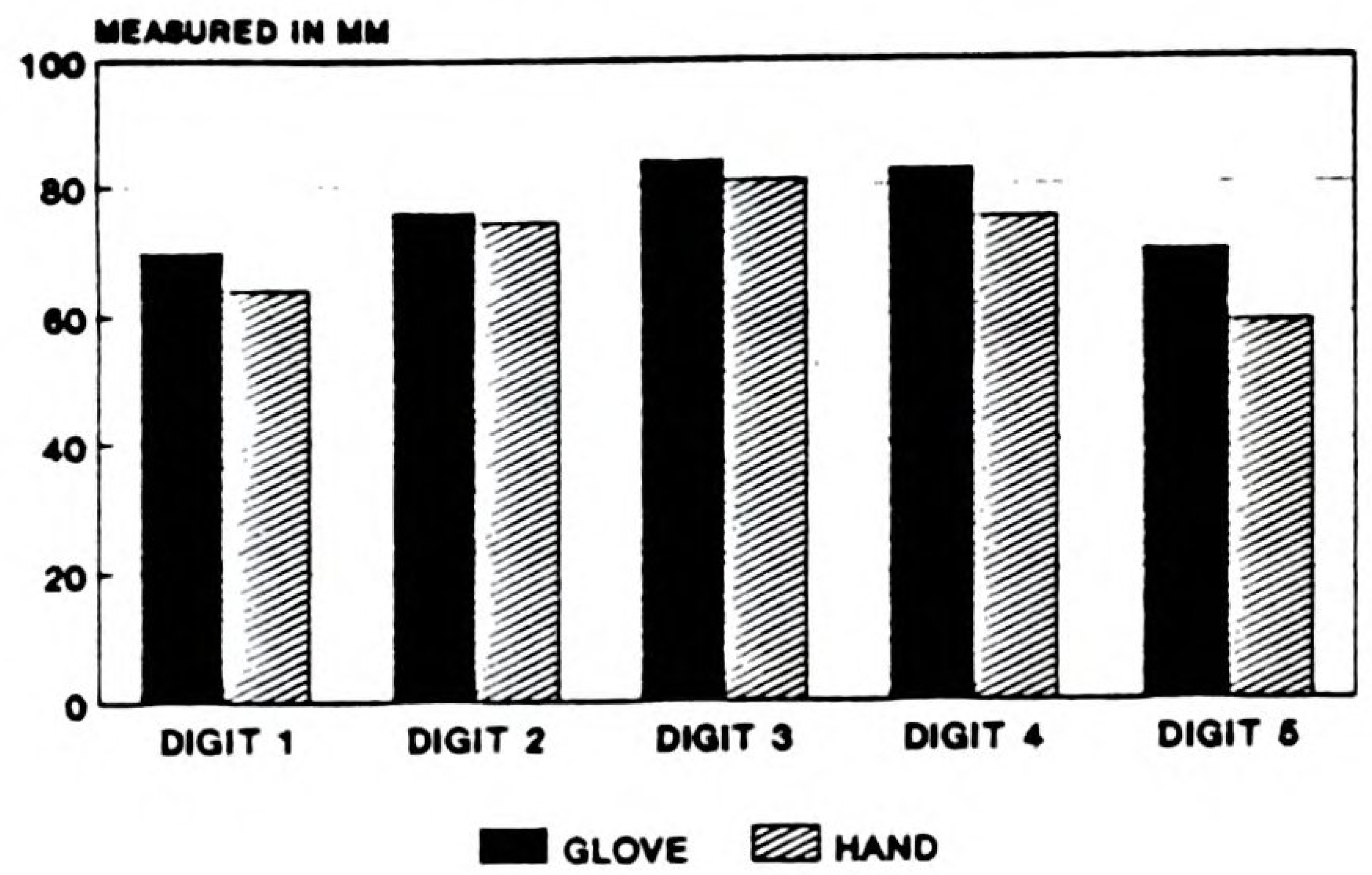


FIGURE 23c
NITRILE--SIZE 10, N=4

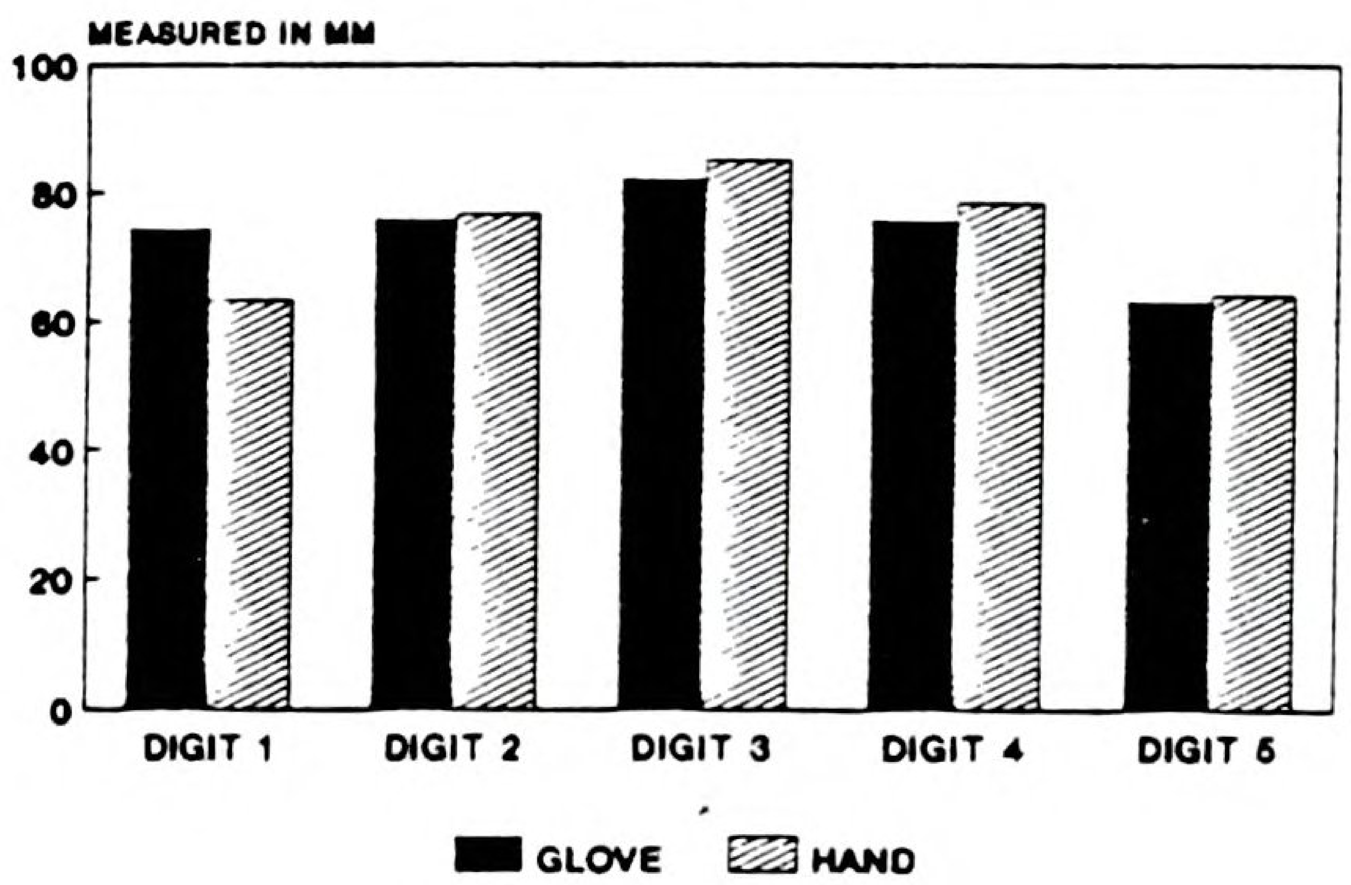


FIGURE 23d
NITRILE--SIZE 11, N=4

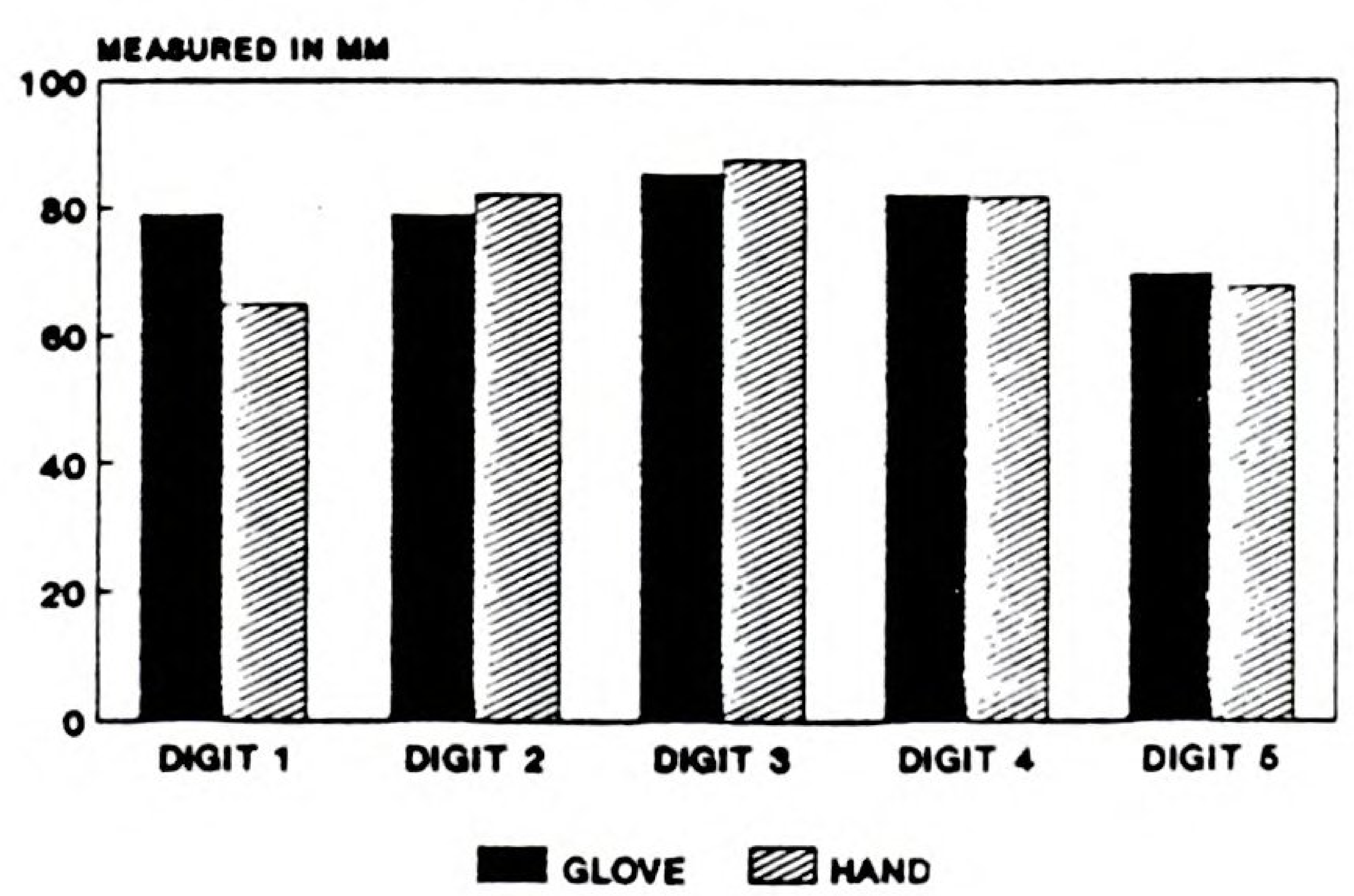


FIGURE 23e
NEOPRENE--SIZE 11, N=2

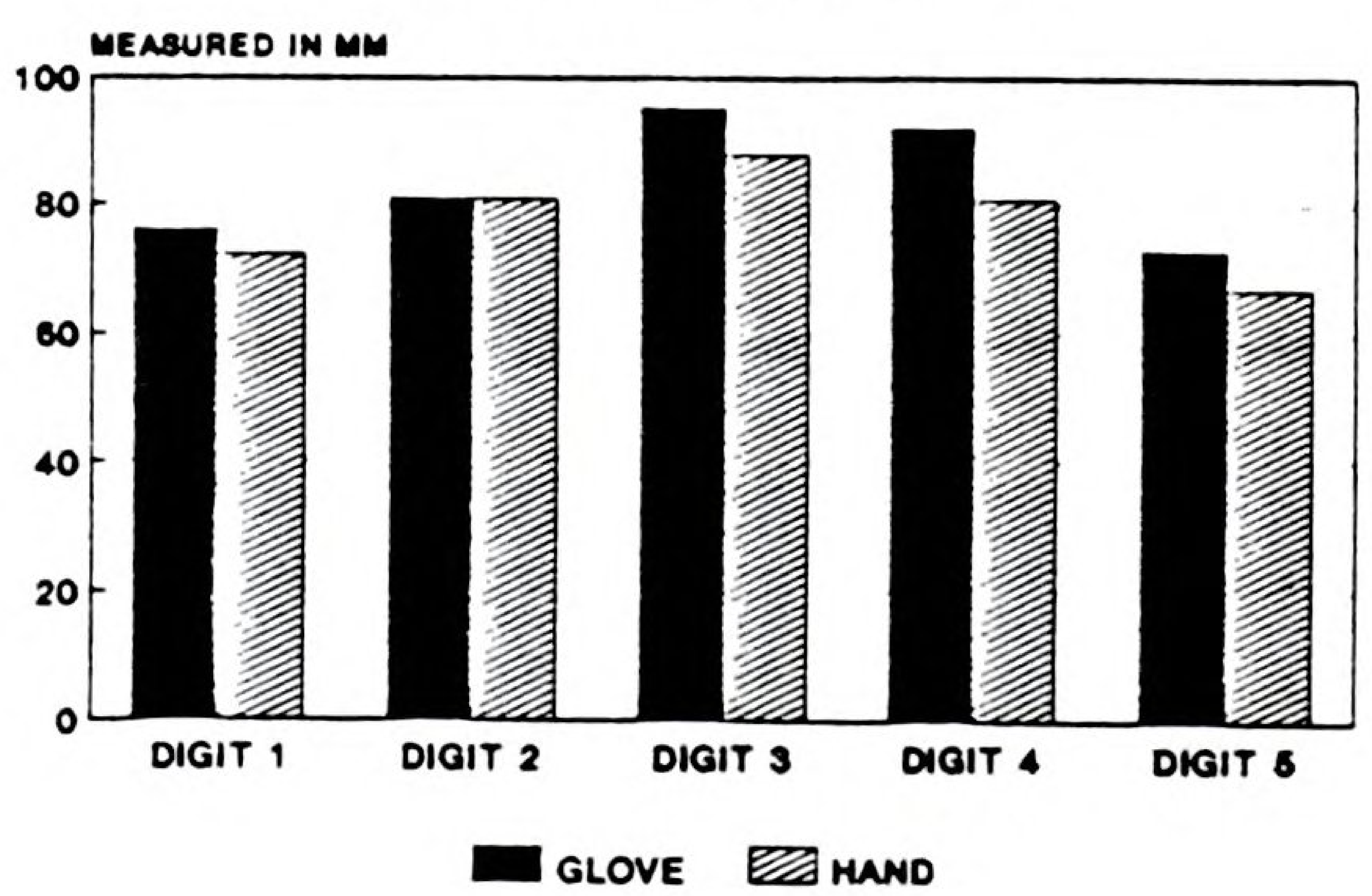


Table 5
Differences Between Glove and Hand Measurements
for Finger & Thumb Diameter

NITRILE, SIZE 9							
	Glove Diameter		Finger & Thumb Diameter		Difference		Percentage of Hand Measurement of Glove Measurement
DIGIT #	IN	MM	IN	MM	IN	MM	
Digit 1	39.25	1.54	21.44	0.84	17.81	0.70	45.372%
Digit 2	34.49	1.36	20.23	0.79	14.26	0.57	41.337%
Digit 3	36.07	1.42	20.38	0.80	15.69	0.62	43.503%
Digit 4	34.49	1.36	18.61	0.73	15.88	0.63	46.034%
Digit 5	32.90	1.30	16.90	0.66	16.00	0.64	48.628%
NEOPRENE, SIZE 9							
Digit 1	46.04	1.81	22.10	0.87	23.94	0.94	51.990%
Digit 2	38.10	1.50	21.07	0.83	17.03	0.67	44.698%
Digit 3	38.10	1.50	20.64	0.81	17.46	0.69	45.820%
Digit 4	38.10	1.50	18.93	0.74	19.17	0.76	50.315%
Digit 5	36.51	1.44	18.40	0.72	18.11	0.72	49.600%
NITRILE, SIZE 10							
Digit 1	40.84	1.61	24.16	0.95	16.68	0.66	40.835%
Digit 2	37.66	1.48	22.04	0.87	15.62	0.61	41.476%
Digit 3	39.25	1.54	21.91	0.86	17.34	0.68	44.175%
Digit 4	37.66	1.48	20.56	0.81	17.11	0.67	45.420%
Digit 5	36.07	1.42	18.54	0.73	17.53	0.69	48.604%
NITRILE, SIZE 11							
Digit 1	42.42	1.67	23.88	0.94	18.55	0.73	43.721%
Digit 2	39.25	1.54	22.43	0.88	16.82	0.66	42.843%
Digit 3	40.84	1.61	22.21	0.87	18.63	0.74	45.610%
Digit 4	39.25	1.54	20.45	0.80	18.80	0.74	47.908%
Digit 5	36.07	1.42	18.20	0.72	17.87	0.70	49.546%
NEOPRENE, SIZE 11							
Digit 1	47.63	1.88	23.05	0.91	24.58	0.97	51.602%
Digit 2	41.28	1.63	21.64	0.85	19.64	0.78	47.571%
Digit 3	41.28	1.63	21.56	0.85	19.72	0.78	47.765%
Digit 4	41.28	1.63	19.90	0.78	21.38	0.85	51.799%
Digit 5	38.10	1.50	18.22	0.72	19.88	0.78	52.178%

FIGURES 24a-24e. COMPARISON OF HAND & GLOVE MEASUREMENTS FOR FINGER & THUMB DIAMETER

FIGURE 24a
NITRILE--SIZE 9, N=1

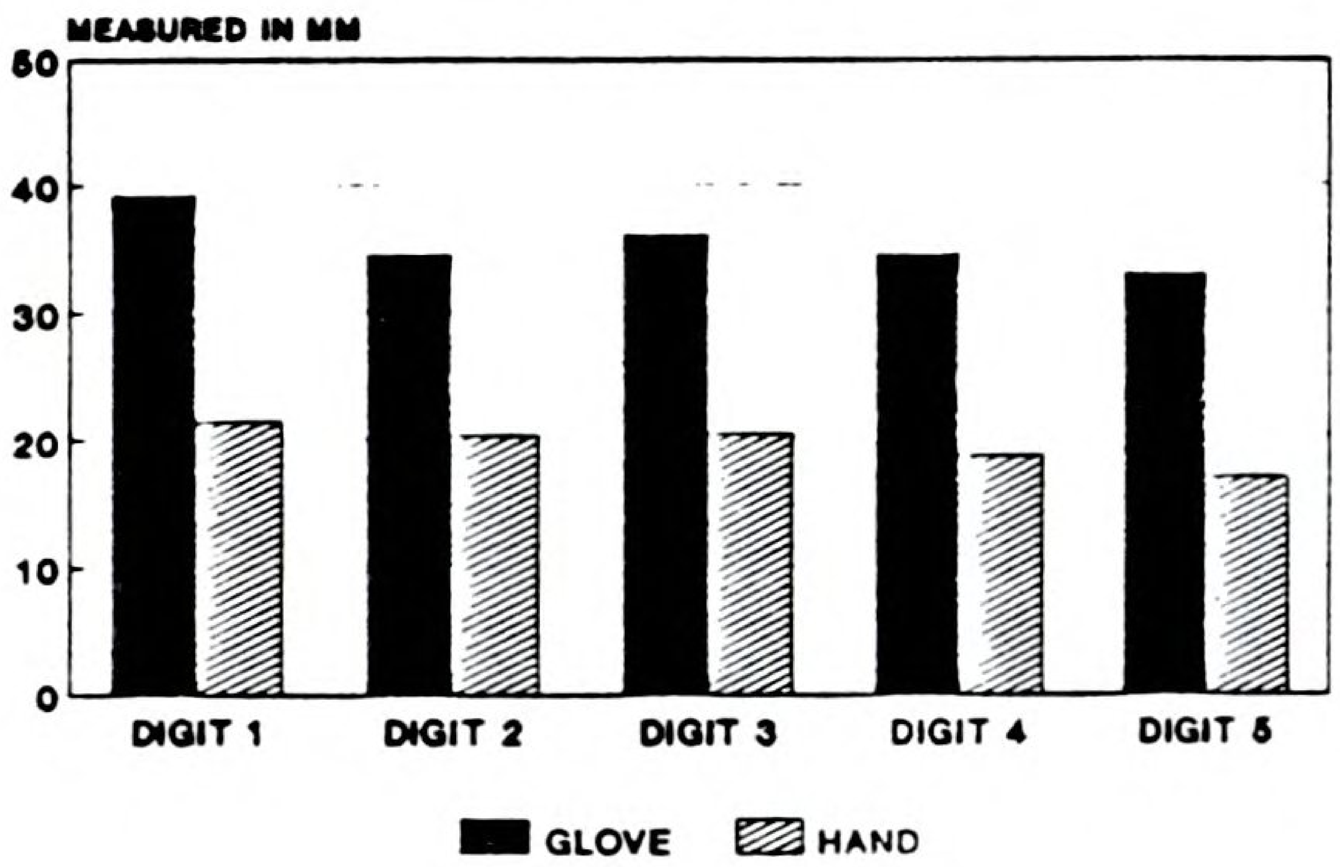


FIGURE 24b
NEOPRENE--SIZE 9, N=1

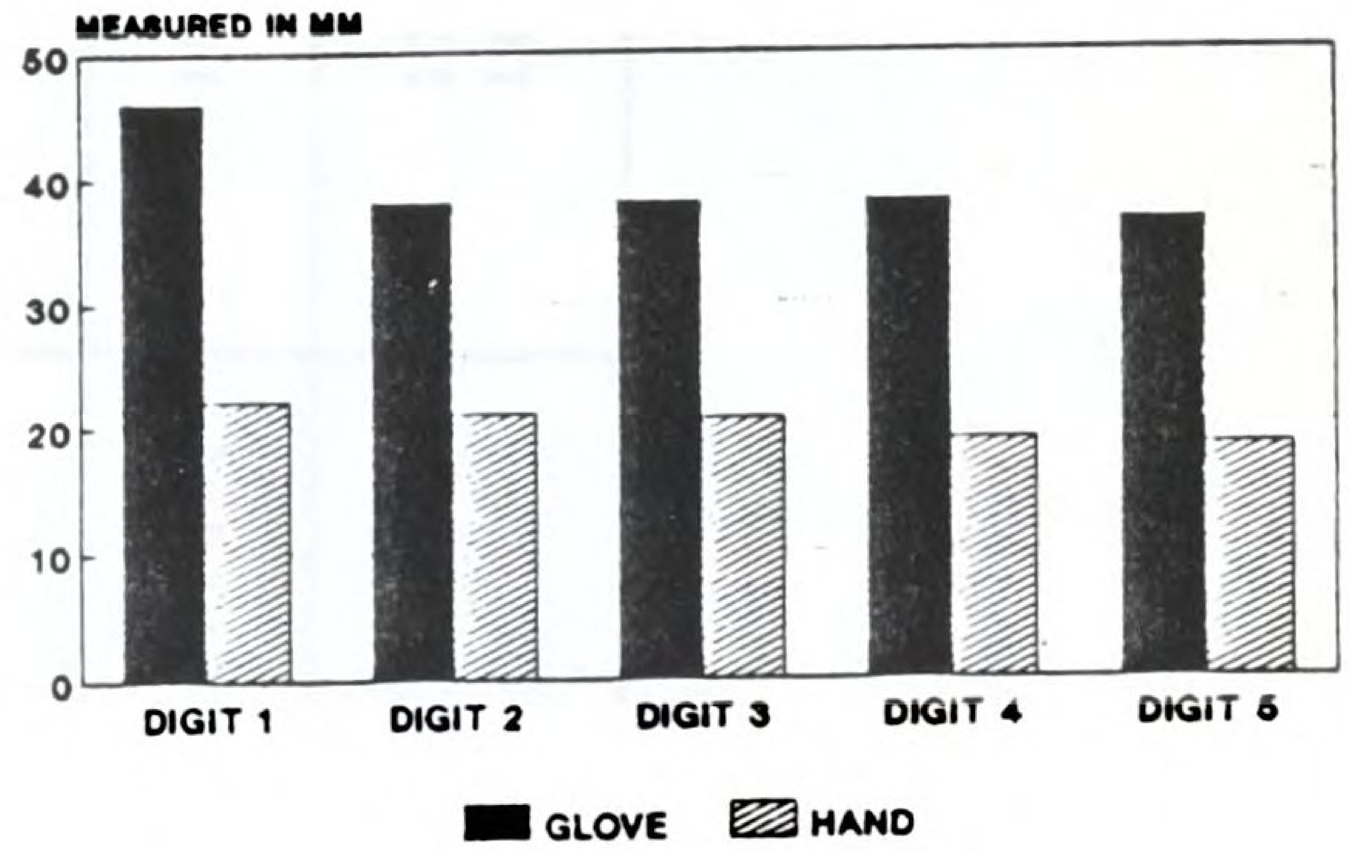


FIGURE 24c
NITRILE--SIZE 10, N=4

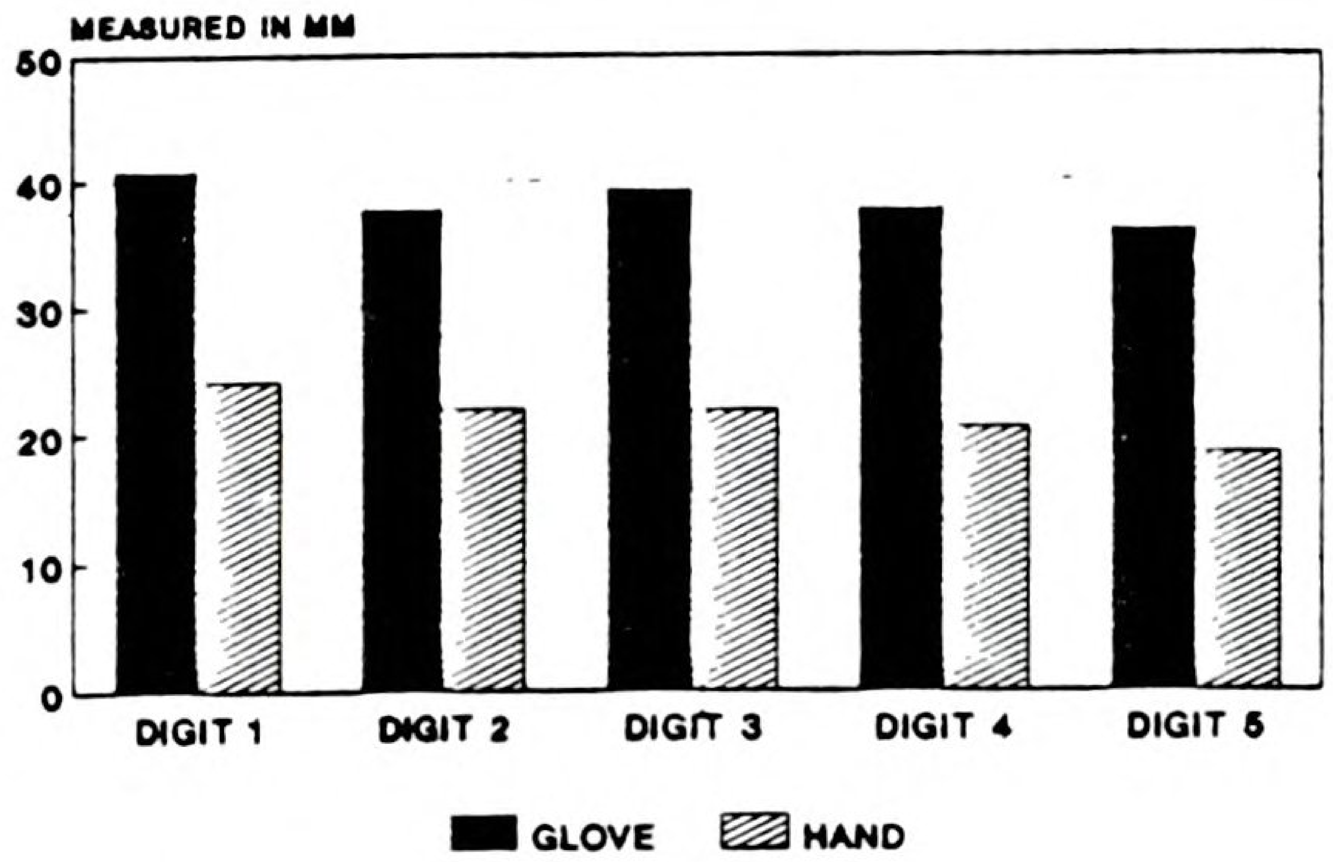


FIGURE 24d
NITRILE--SIZE 11, N=4

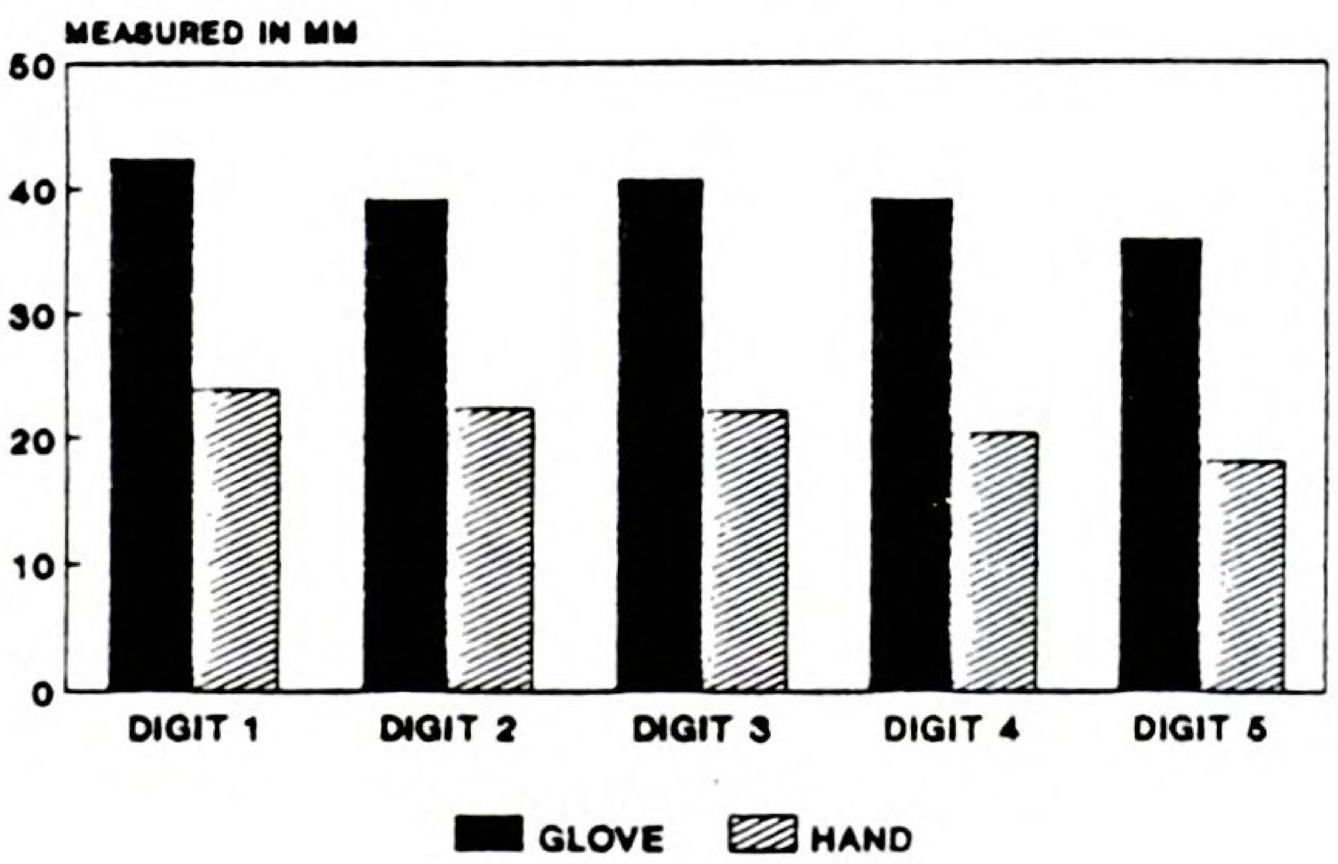


FIGURE 24e
NEOPRENE--SIZE 11, N=2

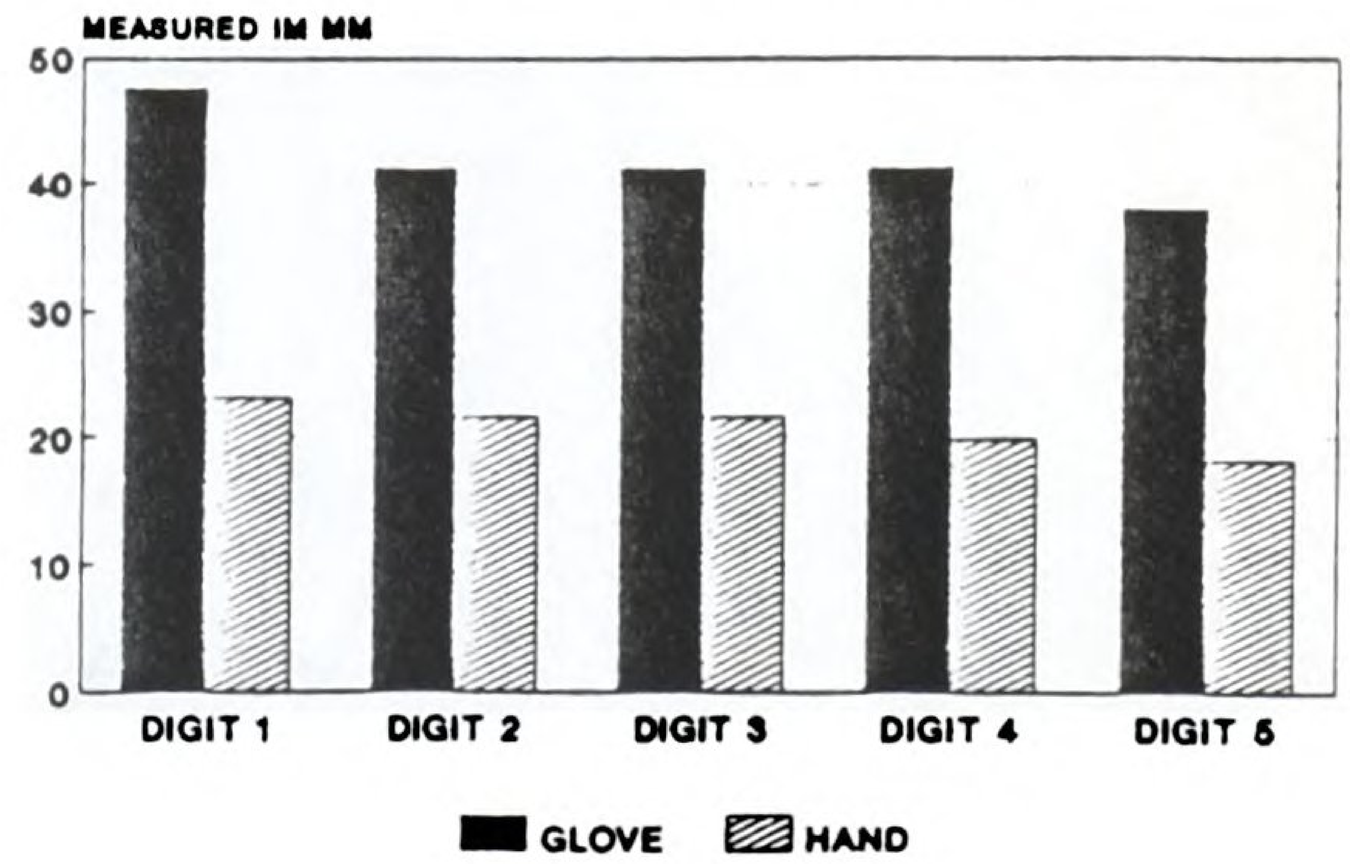


Table 6
Difference Between Glove and Hand Measurements
for Hand Circumference--MM (IN)

Glove Type	Glove Circumference	Hand Circumference	Difference	%Hand Measurement of Glove Measurement
SIZE 9				
NITRILE	234.07 (9.22)	210.28 (8.28)	23.79 (0.94)	10.16%
NEOPRENE	241.30 (9.50)	213.85 (8.42)	27.45 (1.08)	11.38%
SIZE 10				
NITRILE	256.30 (10.08)	229.26 (9.03)	27.04 (1.05)	10.55%
SIZE 11				
NITRILE	275.35 (10.84)	241.13 (9.49)	34.21 (1.35)	12.43%
NEOPRENE	276.23 (10.88)	229.37 (9.03)	46.86 (1.85)	16.96%

FIGURES 25a-25b. COMPARISON OF HAND & GLOVE MEASUREMENTS FOR HAND CIRCUMFERENCE

FIGURE 25a
NITRILE--SIZE 9, N=1; 10, N=4; 11, N=4

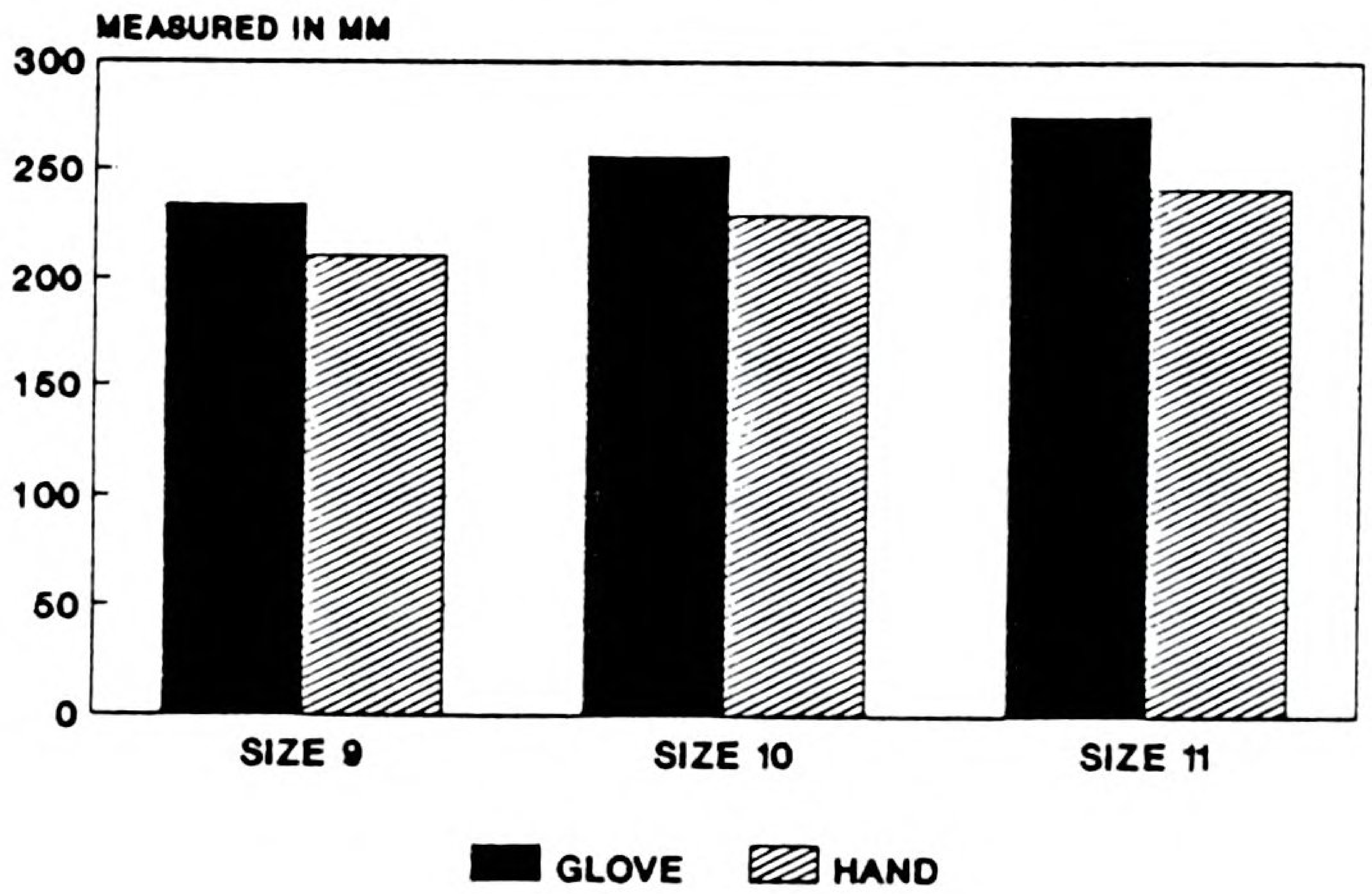
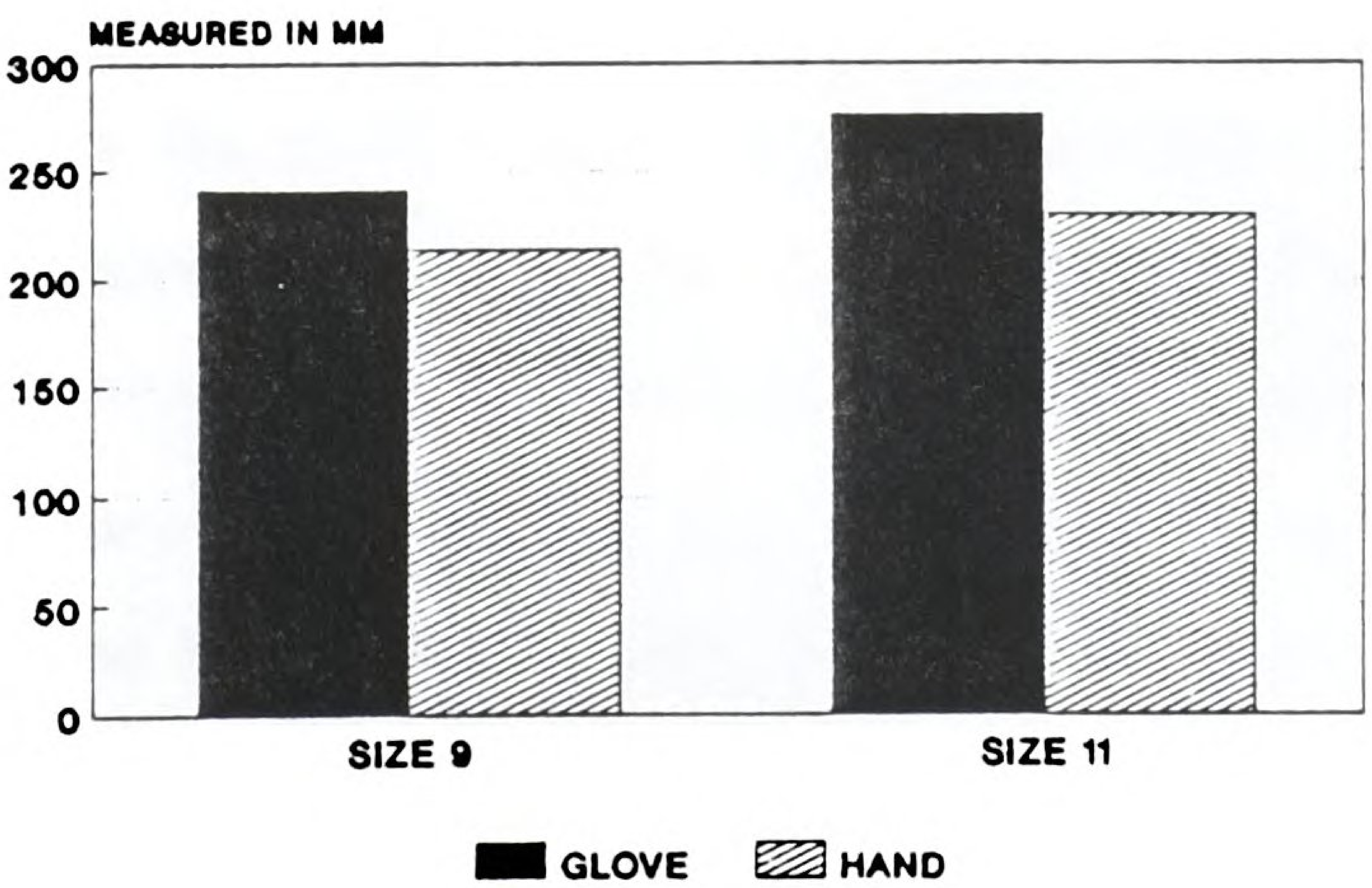


FIGURE 25b
NEOPRENE--SIZE 9, N=1; 11, N=2



measurements. The amount by which hand measurements were, on the average, smaller than the glove's measurements varied as followed: thumb and finger length were from 2.125-14.790% smaller (See Table 4), finger and thumb diameter were from 41.337-48.628% smaller (See Table 5), and hand circumference was on the average 10.164% smaller (See Table 6).

For the size ten nitrile glove, it was found that the participants' measurements for finger & thumb length (See Figure 23c) tended to be larger than the gloves' measurements, but finger and thumb diameter (See Figure 24c) and hand circumference (See Figure 25a) were always smaller than the glove's measurements. On the average, hand measurements differed from the glove's measurements as follows: finger and thumb length were from 15.005% smaller to 3.644% larger (See Table 4), finger and thumb diameter were from 40.835 to 48.604% smaller (See Table 5), and hand circumferences were on the average 10.55% smaller than the glove's measurements (See Table 6).

For the size eleven nitrile glove, it was also found that the participants' measurements for finger & thumb length varied in their relation to the gloves' measurements; two digits were longer and three were shorter than the glove's measurements (See Figure 23d). Participants' measurements for finger and thumb diameter (See Figure 24d) and hand circumference (See Figure 25a) were always smaller than the glove's measurements. On the average, the magnitude of the difference between hand measurements and glove measurements were: finger and thumb length from 18.044% smaller to 3.705% (See Table 4),

finger and thumb diameter from 42.843 to 49.546% smaller (See Table 5), and hand circumference were 12.425% smaller (See Table 6).

These same measurements were compared for the neoprene glove worn by the particpants during the high speed cinematography portion of this study. Only the size nine and eleven neoprene gloves were worn by the high speed cinematogrpahy participants. When the hand and glove measurements were compared for the size nine neoprene glove, the same trend was evident as that for the size nine nitrile glove; e.g. the glove was larger than the hand. The size nine nitrile glove measurements, however, were smaller than the measurements for the size nine neoprene glove so the percentage of difference between the participants' measurements and the gloves' measurements was greater for the neoprene glove.

Comparisons of hand and glove measurements for the size eleven neoprene gloves and the size eleven nitrile gloves showed that both gloves were larger than the participants' hands for the finger and thumb diameter and hand circumference measurements. However, unlike the nitirle glove the size eleven neoprene glove was larger than the participants' measurements for finger and thumb length. This difference in findings is probably due to the fact that the nitrile glove was smaller than the neoprene glove for most measurements.

<u>Summary</u>: Overall, the nitrile gloves measured smaller than the neoprene gloves. This difference in size is most likely the reason that the nitrile gloves' measurements were shorter than the participants' measurements for finger and thumb length while the neoprene gloves were not. Both the nitrile and the neoprene gloves had

larger measurements than the participants' measurements for finger and thumb diameter and hand circumference with the measurements being greater for the neoprene gloves. This indicates that sizing problems are occuring between glove materials. Consumers, therefore, may find gloves of one material fit better than those made from a different material, that gloves from one manufacturer fit better than gloves from another manufacturer, or even that a particular brand of glove made by a manufacturer fits better than another brand of glove made by the same manufacturer.

Relation of Glove Design to Methods of Donning and Doffing

Research Question: Is there a relationship between how pesticide applicators don and doff their gloves and glove design?

From the videotape of pesticide applicators donning and doffing their protective gloves, it was found that not all pesticide applicators use the same method for the removal of their gloves. The videotape also showed that the pesticide applicators did not don and doff their gloves identically each time they were videotaped. Therefore, it was necessary to videotape the pesticide applicators three times each to be able to observe differences in how they don and doff their gloves.

For those individuals who wore non-disposable protective gloves, three methods were used to doff the gloves. The first method was used by three of the five participants(See Table 7, Method 1). Using this method, the pesticide applicator's bare hand only came into contact with the very edge of the glove cuff. One applicator also rinsed his gloves with water before removing them when using this procedure.

Table 7: Steps Observed in Removing Protective Gloves (Nitrile or Butyl Rubber)

METHOD ONE	METHOD TWO	METHOD THREE
1. Grasp fingers on one hand.	1. Grasp fingers on one hand.	1. Grasp the cuff on one hand.
2. Pull to remove glove halfway.	2. Pull to remove glove.	2. Pull the glove halfway off.
3. Grasp fingers of the other glove with the hand that has glove halfway removed.	3. Place removed glove in ungloved hand.	3. Repeat this procedure with the second glove.
4. Remove second glove.	4. Grasp fingers of second glove.	4. Grasp fingers of one hand.
5. Remove first glove by gently letting it fall off the hand while holding the very edge of the cuff.	5. Pull off second glove.	5. Pull the rest of the way off.
		6. Repeat this procedure with the second glove.

The other two applicators were not as careful when removing their gloves. The second method was only used by one applicator (See Table 7, Method 2). With this method, any pesticides that were still on the outside of the gloves would contaminate the hands when the gloves were removed. The other applicator used even a different method for removal (See Table 7, Method 3). Using this procedure resulted in half of the glove being inside out after removal. Therefore, the applicator had to straighten out his gloves after removing them. This caused his bare hands to come in to contact with the outside of the gloves. Another observation made while watching this applicator was that his gloves were too small for his hands. This would cause some of his problems in removing his gloves. If this applicator had properly fitting gloves, he might not have removed them the way he currently does. Therefore, the first method discussed was judged better than the last two methods.

For those pesticide applicators that were videotaped donning and doffing disposable gloves, removal of the gloves without contamination appeared easier than for those wearing reusable gloves. If the applicators planned on reusing the gloves, they used the method for reusable gloves first mentioned for removing the gloves (See Table 8, Method 1). The applicators also used two other methods to remove their gloves (See Table 8, Methods 2 & 3). All of these methods allowed the applicator to remove his gloves without apparent excessive contamination.

These videotaped findings showed the pesticide applicators in this study had a harder time doffing reusable gloves than disposable gloves

Table 8: Steps Observed in Removing Disposable Gloves (Vinyl)

METHOD ONE	METHOD TWO	METHOD THREE
1. Grasp fingers on one glove.	1. Grasp edge of cuff on one glove.	1. Grasp edge of cuff on one glove.
2. Pull to remove glove halfway.	2. Pull glove off, glove is turned inside out when removed.	2. Pull the cuff halfway off.
3. Grasp fingers of the other glove with the hand that has glove halfway removed.	3. Throw glove in waste-basket.	3. Use the glove that is halfway off to grasp second glove by the cuff.
4. Remove second glove.		4. Pull the second glove halfway off.
5. Remove first glove by gently letting it fall off the hand while holding the very edge of the cuff.		5. Let the gloves fall the rest of the way off without touching the outside of the glove.

without contamination being apparent. Only the first method used for removing the reusable gloves assured the pesticide applicator of little exposure. Method two would cause exposure by placing the removed glove in the ungloved hand, and method three would cause exposure at both hands because it would be necessary to turn the gloves right side out. It is believed, however, that this method was used because of poorly fitting gloves. All three methods of removal for the disposable gloves would be acceptable for use because the pesticide applicator was not required to touch the outside of the glove after removal because the gloves are disposed of after use. It is also difficult to remove these gloves without turning them inside out because they fit more tightly. The affect of build-up inside gloves will be tested in another portion of the Michigan portion of the North Central Regional Project 170.

Chapter Six

SUMMARY, DISCUSSION AND CONCLUSIONS

Summary

The purpose of this exploratory study was to determine if pesticide protective gloves inhibited the range of motion of the hands. This study was completed using high speed cinematography to collect data for kinematic analysis of motion of pesticide applicators' hands while performing typical tasks. This study also examined the relationships between applicators' hand shape & size, glove size & design, type of glove worn, and how applicators don and doff gloves. This was completed by interviewing MSU pesticide applicators and their supervisors, taking anthropometric measurements, and videotaping pesticide applicators donning and doffing pesticide protective gloves.

Kinematic Conclusions

Research Question: Can differences in hand motions involving tightening and untightening container caps be differentiated between gloved and ungloved conditions by utilizing three-dimensional kinematic techniques?

Kinematic analysis was completed by using high speed cinematography to collect data for three participants while completing tasks identified as typical for pesticide applicators. The tasks completed were tightening/untightening a container cap and pulling the trigger on a hand held spray gun. Three replications of each task being completed were filmed in both the ungloved and gloved conditions.

Analysis of the data were based on how the tasks were performed when the participant was ungloved and gloved. The range of motion for each action and condition were then compared to determine if the glove was inhibiting the participant's movements. Measurable differences were found in the range of motion between ungloved and gloved conditions in this study. Further study is recommended to both confirm these findings and to determine how other pesticide protective gloves of different thicknesses and/or design alter these actions necessary to the pesticide applicator. It is also important to determine how pesticide protective gloves alter additional actions completed by the pesticide applicator. These findings also indicated that the glove needs to be redesigned to conform to the hand/wrist/forearm so that it does not limit the range and effectiveness of hand/wrist/forearm motion. Designing the glove to conform to the hand/wrist/forearm is consistent with Tremblay's (1989, p. v) findings that tight fitting gloves "interfered the least with finger dexterity."

Observations: Using high speed cinematography as a methodology to quantify hand/wrist/forearm actions for ungloved and gloved conditions revealed that it could provide beneficial data for those individuals interested in the design of protective gloves. Specifically, this study indicated how the range of motion in degrees for the hand in both the ungloved and gloved conditons differed for the actions completed. These results indicated that the hand seemingly was not able to complete as wide a range of motion while in the gloved condition. This could, however, be because the glove moved differenlty than the hand or becasue of soft tissue movement.

Interview Conclusions

Research Question: What types of hand protection, if any, do selected campus pesticide applicators use?

Research Question: What problems do pesticide applicators identify with respect to hand protection?

The researcher concluded from these interviews that campus applicators were not using recommended protective gloves. The main reason for this was the amount of dexterity and tactile quality that the applicators felt was necessary to be able to properly handle their equipment and complete their jobs. This is consistent with findings reported by Tremblay (1989), Bensel (1987), Parsons & Egerton (1985), Williams (1979), Thomas (1976), and Sheridan (1954). Since no pesticide permeation data were available on these gloves, the degree of protection they afford is not known.

Comparison of MSU Participant's Hand Data with the Larger Alberta Sample's Hand Data:

Research Question: What is the relationship between pesticide applicators' hand measurements and (a) other hand data?

The comparison between MSU pesticide applicators and Alberta agricultural workers showed that all MSU hand dimensions fell within the range of measurements taken in the Alberta study. The difference that occurred could be attributed to the broader range of the Alberta study and the ethnicity and age of the participants. Because MSU hand dimensions were found to be representative of a larger sample, the fitting problems found in this study can likely be attributed to a larger sample. Further study of hand measurements for differences occurring because of age/ethnicity could show if the differences observed in this study are real or just a factor of a small sample.

Conclusions on Hand Size and Shape in Relation to Glove

Research Question: What is the relationship between pesticide applicators' hand measurements and (b) glove size?

The measurements taken on the gloves selected as "best fitting" by the participants, finger and thumb length, finger and thumb diameter, and hand circumference, and compared to the participants' measurements showed that the sizing of glove styles was not consistent for different sizes or for different materials. The differences in these measurements will probably instigate changes recommended for the design of protective gloves. The neoprene gloves, therefore, had fewer fit problems than the nitrile gloves for finger and thumb lengths; this was where the main fitting problem occurred. Being larger for the finger and thumb diameter and hand circumference measurements, however, has caused the neoprene gloves to allow excessive room for the hand in the glove. This has created a loss of dexterity for the wearer.

Comparisons made between the gloves' measurements, for both styles and materials, and the participants' measurements showed that glove manufacturers were not sizing finger and thumb lengths to adequately fit the participants. Both the size ten and eleven nitrile gloves demonstrated fit problems with finger and thumb length. It was found that some of the participants' digit lengths were longer than the gloves' digit lengths. Also for the particpants' measurements that were smaller there was only a slight difference from the gloves' measurements.

In contrast to the problem of glove finger and thumb length being too short, Tremblay (1989, p. 91) found that glove finger and thumb lengths needed to be shortened. One possible reason for this

difference in findings is that identical gloves were not used for both studies. Tremblay's (1989) findings were summarized for four different styles of gloves, and the findings for this study were only summarized for two styles of gloves. Only the nitrile glove was used in both studies. This difference in itself indicates that the sizing between glove types or materials is not identical and needs to be studied further by glove manufacturers.

Comparisons made between the gloves' measurements and the participants' measurements for finger and thumb diameter and hand circumference showed that the glove allowed a significant amount of fitting ease for both the nitrile and neoprene gloves. This finding is also in contrast to the fit problem identified for finger and thumb length measurements. Some of the participants' measurements were significantly smaller than the gloves' measurements for finger and thumb diameter which made the gloves big and loose on the digits. Although it is realized that some fitting ease is necessary, large amounts of ease cause a loss of dexterity and feeling for the worker. Tremblay (1989, p. 90) also found that when more ease was allowed for diameter and circumference measurements the "participant's rate of performance decreased." In Tremblay's (1989, p. 76) study it was also identified that there were differences ". . .in the overall mean of the four types of gloves" used in the study. These findings along with the findings of this study indicate that there is no standard amount of ease allowed in gloves. It is, therefore, necessary to complete further research to determine an optimal amount of ease in gloves.

Tremblay (1989, p. 76) also concluded that ". . .further research is needed to define an acceptable 'ease' value for specific hand dimensions."

No sizing problem was evident for finger and thumb length for the size nine gloves or the size eleven neoprene gloves. This sizing problem was probably not evident for the size eleven neoprene glove because when measured it was found to be larger than the size eleven nitrile glove.

Conclusions drawn from this data and Tremblay's (1989) suggest that the present sizing system used by glove manufacturers is not providing the "best fit" for all individuals. It is evident that glove manufactuers size gloves so that more hands will fit in one size. Re-evaluating the sizing system currently used to provide a better fit would most likely suggest that glove manufacturers provide a wider range of sizes. Glove manufacturers, however, will probably be concerned about the cost effectiveness of providng a wider range of glove sizes. Glove manufacturers may find, though, that by providing a better fitting glove they may sell more gloves and offset the cost of producing additional sizes.

Conclusions on Donning and Doffing Different Glove Designs

Research Question: Is there a relationship between how pesticide applicators don and doff their gloves and glove design?

Videotaping showed that participants for this study tended to come into less contact with the contaminated part of the glove while doffing disposable gloves rather than the reusable gloves. This probably occurred because workers normally peel the gloves off without worrying about needing to reuse them again, however, they still were careful to

not touch the outside of the glove more than necessary. These individuals also may be more educated or concerned about the hazards of working with pesiticides.

The videotaping of the participants wearing the reusable gloves also showed that fit is a factor in pesticide exposure. One participant who was wearing gloves that were too small had problems in doffing the gloves. This caused the applicator to come into contact with more parts of the gloves that may have been contaminated by pesticides. This is true both when doffing and when straightening out the glove after removal. It is, therefore, necessary to inform the supervisor who secures the gloves and the applicators of the importance of wearing a glove that fits.

From the videotape, it was also apparent that some of the participants were not aware of safety measures they should be taking when doffing gloves that may have been contaminated by pesticides. This would indicate a need for educating pesiticide applicators in the proper techniques of glove removal for pesticide protective gloves. From the techniques observed during this study, method one (See Table 7) would be appropriate for use by pesticide applicators with one small change. This change being that applicators rinse their gloves before removing them. In general, applicators should also be educated in the health risks associated with pesticides so that they will be more likely to follow safety guidelines when working with pesticides.

<u>Assessment of Motion Study Methodologies</u>:

Another purpose of this study was to evaluate the usefulness of kinematic analysis and videotaping as a type of methodology for

collecting motion data for Clothing & Textiles professionals who are designing apparel for specific functions. The use of kinematic analysis will allow researchers to more precisely determine how clothing alters/constricts the movements of the body by obtaining the angular, time, velocity and acceleration data for the action. Even though all of this data can be calculated, it may not be relative to all studies so researchers should select that which is relevant to their study. When using high speed cinematography to collect data, the motion to be studied will need to be filmed when the participant is unclothed and clothed. This will allow the researcher to obtain data so that comparisons can be made of how the range of motion differs between the conditions. It also appearred that high speed cinematography could be used to evaluate how design or material could affect body motion, although this was not tested in this study.

The kinds of motion problems that are best studied are those that can be filmed by at least two cameras, each having a different but complete view of the movement and targeting scheme. If each camera does not have a complete and different view of the movement and targeting scheme, it will not provide the two sets of two dimensional positions of each target that are necessary for analysis of the motion being performed. Motion problems involving clothing can be studied, but would provide best results with clothing that conforms to the body contour. Clothing that does not conform to the body may mask the kinematic motion involved in the action. This masking was a problem in this study when the targeting scheme was placed on the glove cuff in the pilot study. Because the glove cuff was floppy, it did not give

accurate data on the movement. Therefore, it was necessary to move the targeting scheme from the glove cuff to the participant's forearm. Familiarity with gross body motion is seen as a distinct advantage to the clothing designer. Consideration also needs to be given to the size of targeting scheme in relation to the body part being studied. If the body part is small like the fingers, the targeting scheme may be too large to fit on the body part and still be visible to both cameras while the action is being performed. Smaller and perhaps different types of targets would be helpful. Observations also show that this methodology would not be useful to the researcher who is interested in body movement during donning and doffing of clothing. When the targeting scheme is placed on the clothing and then the clothing is donned and doffed, the targeting scheme disappears from the cameras' views.

Using videotaping to study motion will allow researchers to answer questions of what actions individuals typically take and what modifications need to be made in those actions. This does include the donning and doffing of clothing because no targeting scheme is required to record the body's motions. However, it will not provide you with data to calculate whether or not the clothing is altering/constricting the movement. Videotaping also is an effective methodology for showing a sequence of events. It is beneficial for the researcher who is trying to identify what motions are taking place during an action but who does not want to determine the time, distance, position and angles of the movement.

Recommendations for Further Study:

This study has identified specifications that need to be researched further to be able to rank/prioritize design criteria which is the next step in the model (See Figure 3). The specifications that need further study are:

1. Pesticide protective gloves appear to constrict/alter an individual's motions. To confirm these findings more glove types need to be studied. This will also allow the researcher to determine the aspect of the glove that is constricting/altering the motion.

2. Further research also needs to be conducted to determine what gloves pesticide applicators are wearing and why they are wearing them. For example, what features of the glove do they like? Once this information is collected, the gloves that are preferred by the applicators need to be tested so it can be determined if the gloves are providing any protection for the wearer.

3. Glove manufacturers need to complete a study to determine what gloves indiviudals are using and then combine them into user groups according to occupation. Once this information is gathered, more anthropometric data needs to be collected for each user group and used by the glove manufacturers to develop new sizing for gloves.

4. The amount of "optimal" ease allowed in gloves also need to be determined. This will vary between tasks, gloves, and individuals. Since ease is arbitrary, a large study would be necessary to determine an appropriate amount of ease for gloves.

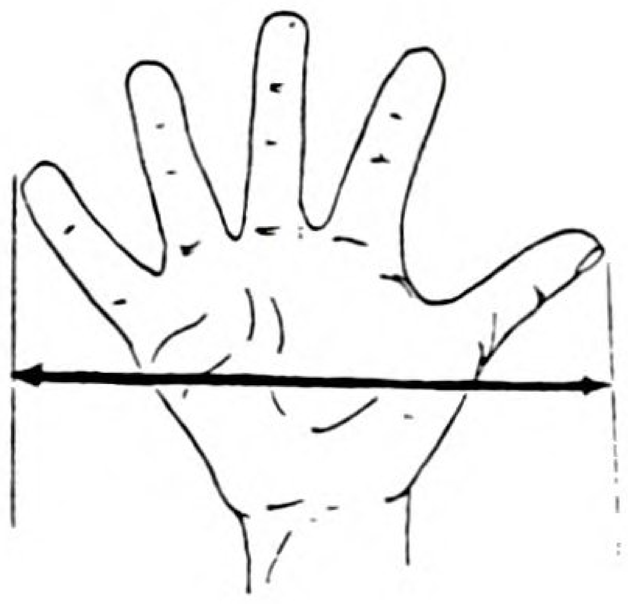
5. An analysis of the internal contamination of gloves in relation to handling needs to be completed. Using the information obtained from this study, a training manual/video needs to be developed to show pesticide applicators how to don and doff gloves to avoid contamination.

6. Research on what safety training is being done for pesticide applicators is also necessary. It does not seem that applicators are aware of what gloves they should be wearing for protection when using specific pesticides/chemicals.

APPENDIX A

DIRECTIONS FOR MEASUREMENT OF THE HAND

FINGER TIP TO ELBOW: Subject sits erect with his upper right (left) arm hanging at his side and his forearm, hand, and fingers extended horizontally. Measure the distance from the tip of the right (left) elbow to the tip of the longest finger.



MAXIMUM SPREAD: Subject spreads the fingers of his right (left) hand with his small finger and thumb parallel to the ruler. Measure the distance from the tip of his small finger to the tip of his thumb.

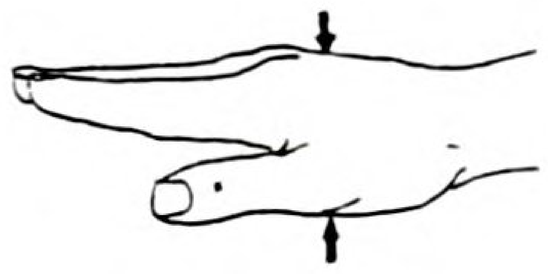
HAND LENGTH: Subject's right (left) hand is extended, palm up. Measure the distance from the lower edge of the navicular bone at the wrist to the tip of the middle finger.

FINGER AND THUMB LENGTH: Subject's right (left) hand is extended, palm up. Measure the distance from the tip of each digit to the deep crease formed where the fingers and thumb fold upon the palm.

HAND CIRCUMFERENCE (at METACARPLE): Subject's right (left) hand is extended. With a soft measuring tape, measure the maximum circumference around the knuckles.

Hertzberg, H.T.E., Daniels, G.S. and Churchill, E. (1954). Anthropometry of Flying Personnel - 1950. WADC Technical Report No. 52-321. Springfield, OH: Carpenter Litho and Printing Co. (Used by Permission.)

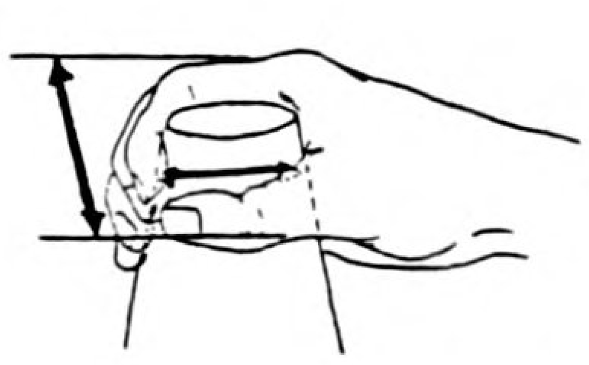
HAND BREADTH (at THUMB): Subject's right (left) hand is extended, palm up, with the thumb lying along side and in the plane of the palm. With the bar of the sliding caliper resting on the palm and the caliper's fixed arm at the knuckle of the thumb, measure the breadth at the right angles to the long axis of the hand.



HAND THICKNESS (including THUMB): Subject's right (left) hand is held with fingers together and extended and with the thumb held against the side of the hand. Using the sliding caliper, measure the thickness from the largest part inside the hand to the dorsal surface of the hand.

FIST CIRCUMFERENCE: Subject makes a tight fist with his right (left) hand, the thumb lying across the end of the fist. With the tape passing over the thumb and the knuckles, measure the circumference of the fist.

FINGER AND THUMB DIAMETER: Each of the subject's fingers and thumb are individually inserted into a series of graduated holes. Record the diameter of the hole which most closely approximates the maximum diameter of the finger or thumb.



GRIP DIAMETER: Subject holds a cone at the largest circumference that he can grasp with his thumb and middle finger just touching.

(1) OUTSIDE: Using the sliding caliper, measure from the joint of 1st and 2nd phalange of the thumb to the knuckle of the middle finger.

(2) INSIDE: Using a sliding caliper, measure the diameter of the cone corresponding to this maximum circumference.

APPENDIX B

CATALOGS SURVEYED FOR GLOVE COUNT

1. Accurate Safety Distributors, Inc.--no date
2. Boss Industrial Glove Catalog--no date
3. D.A. Services, Inc., Defense Apparel--no date
4. Direct Safety Company--1988 Spring Supplement
5. Eastco Industrial Safety Corp.--2nd Revised Edition, 1988 Catalog
6. Edmont--1987 Catalog
7. Gempler's--Mid-Summer 1988 Catalog
8. Industrial Safety--1989 Catalog
9. Lab Safety Supply--1988 General Catalog
10. MSA, Safety Equipment Catalog--1988 Catalog
11. Safety Services Inc.--no date

APPENDIX C

HAND MEASUREMENTS--VIDEO ANALYSIS				
	Participant 1		Participant 2	
	MM	IN	MM	IN
FINGER TIP TO ELBOW	469.900	18.500	488.950	19.250
MAXIMUM SPREAD	222.250	8.750	193.675	7.625
HAND LENGTH	186.590	7.346	197.800	7.788
FINGER & THUMB LENGTH Digit One	56.240	2.214	70.030	2.757
Digit Two	72.850	2.868	78.390	3.086
Digit Three	81.210	3.198	87.130	3.430
Digit Four	76.890	3.027	77.050	3.034
Digit Five	59.070	2.326	65.110	2.564
HAND CIRCUMFERENCE	207.560	8.172	236.080	9.294
HAND BREADTH	103.440	4.072	113.840	4.482
HAND THICKNESS	40.600	1.599	53.420	2.103
FIST CIRCUMFERENCE	288.925	11.375	301.625	11.875
FINGER & THUMB DIAMETER Digit One	21.400	0.843	25.210	0.993
Digit Two	19.970	0.786	22.950	0.904
Digit Three	19.940	0.785	21.740	0.856
Digit Four	19.400	0.764	20.770	0.818
Digit Five	16.580	0.653	19.540	0.769
GRIP DIAMETER Outside	86.630	3.411	73.170	2.881
Inside	41.700	1.642	42.760	1.684

HAND MEASUREMENTS--HIGH SPEED CINEMATOGRAPHY ANALYSIS		
	Participant 3	
	MM	IN
FINGER TIP TO ELBOW	463.550	18.250
MAXIMUM SPREAD	209.550	8.250
HAND LENGTH	185.400	7.299
FINGER & THUMB LENGTH Digit One	63.840	2.513
Digit Two	74.370	2.928
Digit Three	80.750	3.179
Digit Four	74.980	2.952
Digit Five	58.660	2.310
HAND CIRCUMFERENCE	213.850	8.419
HAND BREADTH	101.210	3.985
HAND THICKNESS	46.090	1.815
FIST CIRCUMFERENCE	279.400	11.000
FINGER & THUMB DIAMETER Digit One	22.100	0.870
Digit Two	21.070	0.830
Digit Three	20.640	0.813
Digit Four	18.930	0.745
Digit Five	18.400	0.724
GRIP DIAMETER Outside	94.320	3.714
Inside	47.510	1.871

APPENDIX D

GLOVES WORN BY CAMPUS PESTICIDE APPLICATORS

SUPERVISOR/ APPLICATOR	GLOVE TYPE	TIMES WHEN GLOVES ARE WORN	PROBLEMS WITH GLOVES	FILM YES/NO
1	192 Neoprene--lined by Wells Lamont Claw Hands	Mixing and Cleaning --Uses Vinyl Utility Gloves for applying --Gloves are new at start of season --Worn for season	No dexterity, hot	Yes
2	Vinyl Utility Gloves by Becton Dickinson --prepowdered --nonsterile --disposable --for lab use --ambidextrous	Mixing, Applying, and Cleaning --Disposed of after finished using	Hot, causes hands to sweat	No
3-5	Rubber--medium weight by Edmont, #26-680 --general purpose gloves --non-sterile	Mixing, Applying, and Cleaning --Gloves are new at start of season --Wear for season, replace when see holes, cracks	Hot, causes hands to sweat but applicators really have not complained about them	Yes
6-7	Vinyl Utility Gloves (See Above Details)	Mixing, Applying, and Cleaning --Disposed of after finished using --Most would wear for is two days	Hot, causes hands to sweat Slippery if get oil on them Fingertips and between thumb and index finger break and rip Fit	Yes

GLOVES WORN BY CAMPUS PESTICIDE APPLICATORS, CON'T.

SUPERVISOR/ APPLICATOR	GLOVE TYPE	TIMES WHEN GLOVES ARE WORN	PROBLEMS WITH GLOVES	FILM YES/NO
8-9	Vinyl Utility Gloves (See Previous Page for Details)	Mixing --Disposed of after finished using	Hot, causes hands to sweat	Yes
10	Vinyl Utility Glove (See Previous Page for Details)	Mixing, Applying, and Cleaning --Disposed of after finished using	Hot, causes hands to sweat Accumulates approximately 20-30 mil of sweat in fingertips Fit	No
11	Nitrile Latex by North Hand Protection, #LA 132-6 --Industrial Gloves	Mixing, Applying, and Cleaning --Gloves are new at start of season --Wear for entire season unless they become damaged	Hot, causes hands to sweat	Yes
12	Vinyl Utility Gloves (See Previous Page for Details)	Mixing, Applying, and Cleaning --Disposed of after finished using	Hot, causes hands to sweat Fit	No
13	Vinyl Utility Gloves (See Previous Page for Details)	Mixing, Applying, and Cleaning --Disposed of after finished using --Maximum time worn is 2-3 hours	Hot, causes hands to sweat Sweat may roll out cuff Fingertips break, rip Fit	No
TOTAL NUMBER OF PARTICIPANTS ON CAMPUS: 9				

APPENDIX E

HAND MEASUREMENTS--HIGH SPEED CINEMATOGRAPHY ANALYSIS				
	Participant 1		Participant 2	
	MM	IN	MM	IN
FINGER TIP TO ELBOW	520.700	20.500	473.075	18.625
MAXIMUM SPREAD	234.950	9.250	231.775	9.125
HAND LENGTH	209.550	8.250	206.375	8.125
FINGER & THUMB LENGTH Digit One	73.670	2.901	70.720	2.784
Digit Two	80.400	3.165	81.060	3.192
Digit Three	88.230	3.474	87.590	3.448
Digit Four	80.870	3.184	80.890	3.185
Digit Five	66.650	2.624	67.240	2.647
HAND CIRCUMFERENCE	223.690	8.807	235.040	9.254
HAND BREADTH	108.730	4.281	112.900	4.445
HAND THICKNESS	45.930	1.808	51.100	2.012
FIST CIRCUMFERENCE	280.988	11.063	273.050	10.750
FINGER & THUMB DIAMETER Digit One	23.210	0.914	22.890	0.901
Digit Two	21.730	0.856	21.550	0.849
Digit Three	21.480	0.846	21.640	0.852
Digit Four	20.240	0.797	19.550	0.770
Digit Five	18.370	0.723	18.070	0.712
GRIP DIAMETER Outside	83.380	3.283	81.260	3.199
Inside	47.660	1.876	44.680	1.759

HAND MEASUREMENTS--VIDEO ANALYSIS				
	Participant 3		Participant 4	
	MM	IN	MM	IN
FINGER TIP TO ELBOW	476.250	18.750	482.600	19.000
MAXIMUM SPREAD	234.950	9.250	231.775	9.125
HAND LENGTH	203.200	8.000	206.375	8.125
FINGER & THUMB LENGTH Digit One	58.930	2.320	68.890	2.712
Digit Two	73.330	2.887	78.040	3.072
Digit Three	77.260	3.042	85.710	3.374
Digit Four	75.540	2.974	79.690	3.138
Digit Five	61.210	2.410	65.220	2.567
HAND CIRCUMFERENCE	249.210	9.811	235.970	9.290
HAND BREADTH	121.850	4.797	119.450	4.703
HAND THICKNESS	59.330	2.336	49.750	1.959
FIST CIRCUMFERENCE	307.975	12.125	311.150	12.250
FINGER & THUMB DIAMETER Digit One	25.520	1.005	25.470	1.003
Digit Two	24.550	0.967	23.440	0.923
Digit Three	24.030	0.946	23.730	0.935
Digit Four	21.610	0.851	21.240	0.837
Digit Five	20.110	0.792	19.350	0.762
GRIP DIAMETER Outside	93.220	3.670	95.270	3.751
Inside	42.050	1.656	43.480	1.712

HAND MEASUREMENTS--VIDEO ANALYSIS				
	Participant 5		Participant 6	
	MM	IN	MM	IN
FINGER TIP TO ELBOW	498.475	19.625	485.775	19.125
MAXIMUM SPREAD	234.950	9.250	247.650	9.750
HAND LENGTH	209.550	8.250	206.375	8.125
FINGER & THUMB LENGTH Digit One	67.620	2.663	57.760	2.274
Digit Two	82.810	3.260	77.780	3.062
Digit Three	88.330	3.478	86.360	3.400
Digit Four	81.750	3.219	80.120	3.154
Digit Five	69.910	2.753	66.470	2.617
HAND CIRCUMFERENCE	233.480	9.192	237.410	9.347
HAND BREADTH	117.220	4.615	111.640	4.395
HAND THICKNESS	43.860	1.727	51.730	2.037
FIST CIRCUMFERENCE	336.550	13.250	279.400	11.000
FINGER & THUMB DIAMETER Digit One	24.660	0.971	24.560	0.967
Digit Two	21.350	0.841	21.800	0.858
Digit Three	21.300	0.839	22.230	0.876
Digit Four	19.820	0.780	20.810	0.820
Digit Five	17.950	0.707	18.690	0.736
GRIP DIAMETER Outside	98.620	3.883	86.500	3.406
Inside	46.600	1.835	39.870	1.570

HAND MEASUREMENTS--VIDEO ANALYSIS				
	Participant 7		Participant 8	
	MM	IN	MM	IN
FINGER TIP TO ELBOW	501.650	19.750	508.000	20.000
MAXIMUM SPREAD	228.600	9.000	254.000	10.000
HAND LENGTH	196.100	7.721	209.550	8.250
FINGER & THUMB LENGTH Digit One	60.620	2.387	72.320	2.847
Digit Two	84.660	3.333	87.550	3.447
Digit Three	90.920	3.580	94.110	3.705
Digit Four	85.390	3.362	84.530	3.328
Digit Five	68.110	2.682	70.240	2.765
HAND CIRCUMFERENCE	229.610	9.040	252.230	9.930
HAND BREADTH	108.420	4.269	111.980	4.409
HAND THICKNESS	52.410	2.064	56.130	2.210
FIST CIRCUMFERENCE	285.750	11.250	301.625	11.875
FINGER & THUMB DIAMETER Digit One	21.940	0.864	23.380	0.921
Digit Two	20.710	0.816	23.120	0.910
Digit Three	21.580	0.850	21.930	0.863
Digit Four	19.570	0.770	20.780	0.818
Digit Five	16.040	0.632	18.700	0.737
GRIP DIAMETER Outside	104.290	4.106	107.230	4.222
Inside	49.690	1.957	48.410	1.906

HAND MEASUREMENTS--VIDEO ANALYSIS		
	Participant 9	
	MM	IN
FINGER TIP TO ELBOW	441.325	17.375
MAXIMUM SPREAD	187.325	7.375
HAND LENGTH	182.960	7.203
FINGER & THUMB LENGTH Digit One	59.330	2.336
Digit Two	69.310	2.729
Digit Three	76.560	3.014
Digit Four	69.480	2.736
Digit Five	55.720	2.194
HAND CIRCUMFERENCE	210.280	8.279
HAND BREADTH	105.350	4.148
HAND THICKNESS	47.360	1.865
FIST CIRCUMFERENCE	276.225	10.875
FINGER & THUMB DIAMETER Digit One	21.440	0.844
Digit Two	20.230	0.797
Digit Three	20.380	0.802
Digit Four	18.610	0.733
Digit Five	16.900	0.666
GRIP DIAMETER Outside	76.080	2.995
Inside	37.670	1.483

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