ERGONOMIC EVALUATION OF VINEYARD SYSTEMS

FINAL REPORT

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PREFACE

This is a report on the goals, methods, implementation and results of the Ergonomic Evaluation of Vineyard Systems Project of the University of California Agricultural Ergonomics Research Center, as proposed to and funded by the National Institute for Occupational Safety and Health, Grant # 5 R01-OH 03906. This project commenced June 1, 2000, and terminated on May 30, 2004.

This report is intended to serve as the final project report. Publications emanating from the project up to the time of report submission are attached.

The principal investigators, staff, and cooperators involved express their appreciation to the NIOSH Community Partners for Healthy Farming program and to Ms. Terry Palermo and Ms. Janet Ehlers, NIOSH project officers for their unstinting support in making the project possible and successful.

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LIST OF ABBREVIATIONS

AERC: Agricultural Ergonomics Research Center

LMM: Lumbar Motion Monitor

MAS: Motion analysis system

MSD: Musculoskeletal Disorder

NIOSH: National Institute for Occupational Safety and Health

REBA: Rapid Entire Body Assessment

UC: University of California

UCD: University of California, Davis

VSP: Vertical Shoot Positioned

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ABSTRACT

The agriculture industry has been recognized as one of the Nation's most hazardous industries along with mining and construction, and California's agriculture industry is no exception. The most commonly reported injuries within California agriculture, in general, and the winegrape industry in particular, have been associated with musculoskeletal disorders (MSDs). Grape vineyards utilized for the production of wine are prominent and extensive in northern California with more than 400,000 acres situated primarily in the Sonoma and Napa valleys. Approximately half of the existing commercial wineries in the US are located in California, employing more than 31,000 workers per year with an additional 40-50,000 workers hired specifically for the harvesting season. There is currently an incomparable degree of new winegrape vineyard planting in process throughout the Western States. This is in part due to the rapid expansion of production capacity to meet growing worldwide demand.

As new plantings are made, growers face a rare opportunity to reconsider otherwise more or less fixed structures as well. Chief among these are decisions about trellising systems. Trellises are used to create a greater plant canopy surface area to receive more sunlight and increase production. Trellis systems dictate the health effects, mostly in terms of musculoskeletal disorders, on workers performing pruning and harvesting tasks. However, unfortunately, this is not a current focus in trellis system selection since little is known about these effects, and labor costs are generally cheap.

To address the void about the effects of trellis systems design on MSDs risk factors for workers performing pruning and harvesting tasks, the study's main goals included:

1. Identify and develop detailed ergonomics measurements of risk factors for musculoskeletal disorders for each of the most commonly used winegrape trellis systems.
2. Facilitate use of information about risk factors for musculoskeletal disorders associated with most commonly used winegrape trellis systems in trellis decision-making.
3. Develop practice and design parameters for reducing ergonomics risk factors associated with most used trellis systems.
4. Add to research knowledge about the association of specific agricultural workplace ergonomics risk factors and musculoskeletal disorders and their symptoms.

To achieve the project's primary goals, five main studies were conducted: 1) California Major Trellis Systems, 2) Ergonomic Evaluation: Pruning Simulation, 3) Ergonomic Evaluation: Harvest Simulation, 4) Ergonomic Evaluation: Field Observations, and 5) Field MSD Symptom Surveys. The project involved over 200 vineyard workers and spanned over several pruning and harvesting seasons.

These studies demonstrated the relative risk of developing MSDs among five of the common trellis systems used in the winegrape industry: The Lyre, Vertical Shoot Positioned (VSP), Smart Dyson, Scott Henry, and VSP 4x4. The project has shown that, for both pruning and harvesting, the Lyre and VSP 4x4 systems made workers assume relatively extreme trunk postures, and resulted in increased awkward wrist postures when compared with the other trellises. These combined awkward postures are expected to increase the risk of developing MSDs of both the wrist and the back. Furthermore, the Lyre system places increased MSD risk on the shoulders. On the other hand, all the studies conducted in this project consistently found that the VSP system, overall, resulted in both the least time spent in awkward trunk postures, combined with acceptable wrist and shoulder postures.

The significance of these findings should have important implications to vineyards that are currently considering to plant or re-plant new vines. For a given grape variety, the trellis height does not substantially affect grape quality or vine productivity. Hence, in our efforts to reduce the risks of developing MSDs of the back and upper limbs, we have been, through various means, disseminating the findings of this study to the winegrape industry. The major message relayed is to advocate the use of the VSP system (around 42 inches), and to avoid the VSP 4x4 (around 24 inches) and the higher (above 44 inches) Lyre systems.

SIGNIFICANT FINDINGS

The findings of this study could have important impact on vineyard workers health, especially for vineyards that are considering replanting or expanding into new winegrape acreage.

Based on the multiple studies conducted in this project, the following significat findings can be reported:

1. The design characteristics of the winegrape trellis system clearly affect risk factors for developing musculoskeletal disorders of the back and the upper limbs.
2. The study found that the Vertical Shoot Positioned (VSP) system to be the optimal design, which provide relatively acceptable levels of risk while pruning and harvesting.
3. The results of the biomechanical studies, corroborated with the field observational and symptom surveys, have consistently found that the VSP 4x4 trellis system clearly places the workers at increased risk of developing MSDs of the lower back, and potentially MSDs of the upper extremities
4. The Lyre system caused workers to undergo extension of the spine, which is a risk factor of low back disorders; combined with potential for developing MSDs of the shoulders. Furthermore, this system required the longest harvest cycle time and a high rate of cuts/second during pruning.
5. The Smart Dyson (and potentially the Scott Henry system) required a long harvest cycle time, which could magnify the MSD risk reported in the biomechanical studies.
6. The detailed biomechanical studies have revealed interesting, and previously not explored, interactive relationships between trunk postures and wrist postures.

TRANSLATION OF FINDINGS

Implementing the recommendations that stemmed for the study's significant findings should help reduce the likelihood of developing musculoskeletal disorders of the lower back and the upper extremities among vineyard workers. These recommendations include:

1. The VSP trellis system should be the preferred system to build when planting new grape vines that require hand pruning and/or hand harvesting. The cordon/head height should be maintained around 42 inches.
2. The Lyre trellis system, although it may appear to be a desirable system since workers are mostly in the upright posture, should be avoided since it places increased risk to the shoulders and potentially to the back. This system may become more favorable if the cordon/head height is lowered to around 42 inches.
3. The VSP 4x4 should not be one of the systems that merit consideration when planting new vines. This system places substantial risk for developing low back disorders among vineyard workers who prune and harvest this system.
4. The Smart Dyson and the Scott Henry may impose moderate risk to the workers due to their more complicated vine arrangement.

It should be emphasized that these recommendations should be coupled with previous recommendations that resulted from a recently completed vineyard project by our group, which focused on finding interventions for reducing MSD risks during the lifting, carrying, and dumping phases of the harvest task. These phases are believed to pause the highest risk to workers for developing low back disorders.

Cooperating wineries and vineyard companies and their workers received information on the project and its results through participation in regular meetings. Other industry audiences were reached during the project by staff presentation at regular industry update meetings, and through several state and national industry presentations. Several industry publications have been published, or are in press, outlining the study's main findings. Throughout the project, the team met with staff of California OSHA Education and Training team and State Compensation Insurance Fund to help further disseminate the study's recommendations.

INTRODUCTION

Each year in the United States, approximately one million people report injuries resulting from work related musculoskeletal disorders (MSDs) leading to time away from work for the treatment and recovery of predominantly lower back and upper extremity injuries (National Research Council, 2001). Furthermore, the estimated worker compensation costs associated with WRMSDs range between $45 and $54 billion annually. The National Institute of Occupational Safety and Health (NIOSH) has determined that musculoskeletal injuries rank first in frequency among workers, with approximately half of the nation's workforce being affected (Bernard, 1997; NIOSH, 2004).

The agriculture industry has been recognized as one of the Nation's most hazardous industries along with mining and construction (BLS, 2004; McCurdy and Carroll, 2000; NIOSH, 2004), and California's agriculture industry is no exception. Many agricultural workers in California suffer from an excessive number of work related injuries (NIOSH, 2004). The most commonly reported injuries within the California agricultural industry have been associated with musculoskeletal disorders (MSDs) (AgSafe, 1992; McCurdy et al., 2003; Villarejo, 1999). In the winegrape industry alone, a MSD prevalence of 80 per 1000 workers was reported (Meyers, 2000). The most commonly recorded injuries were attributed to MSDs of the lower back and the upper extremities. These are most likely due to the highly forceful and repetitive hand intensive movements combined with frequent stooped postures common to the majority of the tasks.

Grape vineyards utilized for the production of wine are prominent and extensive in northern California with more than 400,000 acres situated primarily in the Sonoma and Napa valleys. In 1997, the production of winegrapes within California was estimated to account for over 95% of grapes crushed within the U.S. Approximately half of the existing commercial wineries in the US are located in California, employing more than 31,000 workers per year with an additional 40-50,000 workers hired specifically for the harvesting season (Meyers, 1999).

There is currently an incomparable degree of new wine grape vineyard planting in process throughout the Western States. This is in part due to the rapid expansion of production capacity to meet growing worldwide demand. However, in this decade, many existing wine grape vineyards have developed phyloxera, a disease thought to have been eradicated with new clones in the 1960's. With this disease's reappearance in the Napa/Sonoma region, there has been a steady pace of replanting existing properties as well. As new plantings are made, growers face a rare opportunity to reconsider otherwise more or less fixed structures as well. Chief among these are decisions about trellising systems. Trellises are used to create a greater plant canopy surface area to receive more sunlight and increase production. While there are a variety of trellising systems, there are few predominant in the Napa/Sonoma region. Trellis systems dictate the health effects, mostly in terms of musculoskeletal disorders, on workers performing pruning and harvesting tasks. However, unfortunately, this is not a current focus in trellis system selection since little is known about these effects, and labor costs are generally cheap.

SPECIFIC AIMS

To address the void about the effects of trellis systems design on MSDs risk factors for workers performing pruning and harvesting tasks, the study's specific aims included:

1. Confirm cooperating partners from among existing project partners or industry volunteers
2. Determine the most used trellis systems in California (new aim)
3. Develop detailed ergonomics measurements (biomechanical, metabolic, and postural) of identified risk factors for MSDs involved in seasonal job tasks for most commonly used trellis systems.
4. Estimate the effects of each trellis system on workers' musculoskeletal symptoms.
5. Develop trellis-specific cultural practice and engineering design parameters for reducing ergonomics risk factor exposure for most commonly used trellis systems.
6. Evaluate trellis-specific practice and design parameters and field demonstration for risk factor reduction effects.
7. Develop industry specific information on ergonomics risk factors associated with trellis systems.

8. Disseminate project findings to winegrape and other agricultural industry groups, to workers, and to community interests.
9. Report project findings in appropriate research and professional publications.

Background And Significance

Agriculture in California

California is the nation's leading agricultural state with farm income estimated at over $25 billion in 1996, exceeding that of states numbers two (Texas) and three (Iowa) together. California has some 82,000 farms. "Full-time" farmers operate nearly half. About 19% are owned by non-farmers and operated by professional farm management companies. California is home to some 350 farm management companies (Villarejo, 2003; Villarejo, 1999). California agriculture is highly diverse, featuring over 200 commodities, most of which are high value per acre cash crops. California agriculture produces an estimated $1200 per acre compared with a value of $209 for the nation as a whole. California produces over 50 % of the nation's fruit, nuts, and vegetables on about 3% of its farmland. California is also the nation's first ranked dairy production state. California agriculture encompasses some 31 million acres, about 8.5 million of which are irrigated. Agriculture uses about 85% of the state's water supply.

While California agriculture is large scale, featuring high levels of technology, capital, and management investment, it also depends heavily on farm labor, employing more than 750,000 workers per year. It is estimated that some 80% of all farm work in California is performed by hired workers accounting for an estimated 25% of production costs (Villarejo, 2003; Villarejo, 1999). Most are from Mexico and elsewhere in Latin America. According to a labor survey, some 60% of these workers are settled and about 37% are migrant (Mines and Martin, 1986). This readily available supply of cheap labor has not only slowed the pace of mechanization, but has served to preserve many occupational practices long abandoned in other industries. Many harvesting methods, materials handling methods, and hand tools commonly used have remained unchanged for more than half a century (e.g., hand labor, manual materials handling, hand clippers, cutting knives, hoes and shovels). Further inhibiting change, agriculture in California involves over 200 commercial commodities, meaning that farm owners are understandably wary of presuming that technologies or interventions proven in more standardized industrial settings are relevant or appropriate to their particular needs and situation. While there are active unions in the state for farm workers, most work outside the unions and there has been an increase in the employment of workers through independent farm labor contractors.

Workplace MSDs in California Agriculture

A study of a 10 year data base of reported injuries and found an overall rate for non-fatal injuries (4.6 per 100 workers) for California agriculture, putting agricultural work well above the average reported for other workers in California (3.5 per 100 workers) (AgSafe, 1992). In the absence of a reliable surveillance system, these data are most likely incomplete. The AgSafe report notes that with respect to figures for incidence and rates, the data are uncertain for a number of reasons and should be considered an underestimate. Workers advocates suggest that true incidence is more than likely twice that reported by AgSafe. As a result of comparatively high injury rates in agriculture, California OSHA has designated it a high risk industry subject to focused enforcement and prevention programs, including a Targeted Industries Program implemented by cooperating state and federal agencies. Nationally, agriculture has been considered the Nation's most hazardous industry in which to work since about 1988, when fatality rates surpassed those of mining (BLS, 2004; NIOSH, 2004).

AgSafe (1992) estimated that 43% of all reported non-fatal disabling injuries in California agricultural work were sprains and strains. Reported causes emphasized overexertion at about 25% and being stuck by something at about 28%. Taken together, these observations suggest a high prevention priority for ergonomic risk factors. An analysis of five years of injury data (1985-1990) from California agriculture conducted by UCAERC reveals a similar pattern.

While these estimates are crude and little detailed information exists, two current studies by the University of California add to the growing concern for the group of injuries described as musculoskeletal disorders. In studying the injury and illness records of three large commercial plant nursery operations in Southern California for a 24 month period, a study reported finding evidence of at least 85 musculoskeletal disorders involving 1246 lost workdays for a combined worker population of 1290 (Meyers et al., 1997).

Unpublished information shared by worker's compensation providers suggests that average cost for upper extremity MSDs in California agriculture is nearly $10,000. Using an estimated industry-wide rate midway between the figures cited above for vineyards (14.95/100) and nurseries (6.6/100) of 10.8/100, we estimate the real number of MSDs occurring in California agriculture may be on the order of 81,000 per year. We know many of these injuries, perhaps up to half, are unreported, but that would still put annual estimated costs at around $500,000,000.

Perhaps of greater concern, is the human toll of countless workers leaving the agricultural workforce in their 30's or 40's each year due to physical disability deemed normal or expected with age. Because agricultural work in California is physically demanding, most workers in the fields are in their 20's. We rarely find significant numbers of workers on field crews in their 40's. These middle aged workers are leaving the agricultural workforce largely voluntarily because we do not provide adequate workplace prevention and because they cannot physically continue.

Winegrape Production and MSDs in Vineyard Tasks

Grapes rank as the second largest cash crop in California agriculture with a 1994 total value of over $2.3 billion. Wine grapes constitute a significant portion of that total and occupy more than 400,000 acres. Plantings of wine grape vineyards are increasing throughout the state at a rapid rate, in fact, wine grapes are one of only two major California agricultural commodities that are increasing significantly in acreage, employment and production annually. California is now home to over half of the wineries in the United States. The other fastest growing wine grape production regions in the United States are in Washington and Oregon.

This research will take place in northern California, with winegrape vineyard operations in Napa and Sonoma Counties. While the winegrape industry is expanding rapidly along the central and southern coasts and in San Joaquin Valley, this area remains the state's premier wine production center and it constitutes the largest and most productive premier winegrape area in the nation. Many of the state's and the world's largest and best known wine producers are located in this area. Producers in this area still account for nearly half of all winegrape acreage in the

California. As in other commodities producers range in scale and income with most falling into either small (under $20,000 annual income) or large (over $100,000 annual income) categories. However, as with other commodities, large producers account for over 95% of production, sales and employment. The region is also an important administrative center for the industry. There are over 110 wineries represented in the Napa Valley Vintners Association alone.

Wine grape production is a highly competitive business, with great variations in prices paid per ton based on the history of wines from particular regions and vineyards. While machine harvest of wine grapes is making inroads, producers in the Napa /Sonoma region and other coastal areas remain largely committed to hand cultivation and harvest, and a growing number are adopting fully organic production practices. Reasons for this commitment to labor intensive practices include concerns for potential damage to grapes, unpredictable needs to adjust to weather effects, plantings on hilly terrain in high priced regions, and wine marketing concerns. The result is that premium wine grape production (where greatest profits are made) appears very likely to remain a largely labor intensive practice for the future.

The California vineyard industry employs more than 31,000 workers per year. As scale of production increases, the number of workers employed is increasing proportionally. The employee population is dominated by workers from Mexico or other Central American countries. The majority of these workers are not migrant, but are settled in California with their families (Mines and Martin, 1986). In all respects, this is an underserved population. Most speak Spanish only or as a primary language, and most have little or no formal education (including basic literacy). Communication is further complicated by cultural differences. Wages are low (minimum wage) for most jobs and there is a labor surplus, especially for permanent jobs with benefits. There is virtually no labor organization in this industry and most workers are employed directly by the enterprise, not by farm labor contractors.

In the winegrape industry alone, a MSD prevalence of 80 per 1000 workers was reported (Meyers, 2000). The most commonly recorded injuries were attributed to MSDs of the lower back and the upper extremities. These are most likely due to the highly forceful and repetitive hand intensive movements combined with frequent stooped postures common to the majority of the tasks. Ergonomic job screening by our research group provided substantial evidence of ergonomic risk factors across the full scope of seasonal vineyard job tasks. These tasks included: 1) harvest, hoeing/weeding, 3) cutting heads, 4) pruning, 5) pre-pruning, 6) staking, 7) planting, 8) vine training, 9) shoot positioning, and 10) leaf removal. It was in the conduct of this work, that we became aware that differing trellis systems had a potentially predominant role in determining task specific ergonomic risk factors. The top two tasks that could potentially be affected by the trellis system design are hand **pruning** and **harvesting**. Hence the focus of this project was on these two tasks.

Hand Pruning

Hand pruning is characterized as the traditional mode of pruning practiced in most wine producing vineyards. This pruning technique is primarily used for head trained and cordon trained vines. Head trained and cordon trained vines can be generally described as methods used to determine the growth characteristics of the vine. Head trained vines involve the growth of canes (fruiting units) from the top of the central region of each vine as shown in Figure 1. Cordon trained vines are described as the permanent arms that stem from the trunk of each vine as shown in Figure 2.

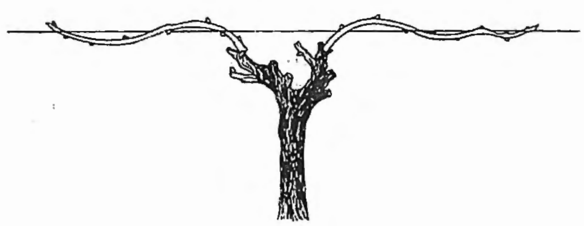


Figure 1. Head trained vine.

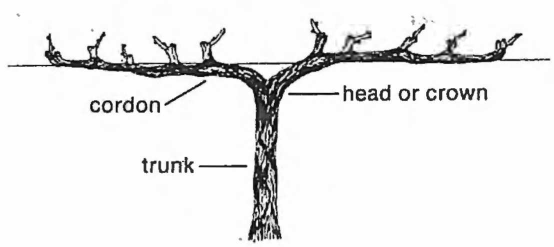


Figure 2. Cordon trained vine

Cordons may be trained for growth in the horizontal and vertical planes with unilateral, bilateral, or quadrilateral orientations. The functions of the cordons are for the support and growth of the fruit bearing units known as the spurs and/or canes of each vine.

The primary responsibility of the pruner is to ensure the proper pruning of each trellis system based on the desired characteristics of each vine. The viticulturist responsible for the grape producing operation has predetermined the specifics of pruning (i.e. location of cuts and number of nodes to be remained) that will yield the optimal and highest quality grape. The pruner will prune each type of trellised vine in a specified manner based on the variety of grape produced.

The physical conditioning of the pruner can be very demanding requiring workers to be capable of working on their feet and constantly moving for an entire 8-hour work-shift. The principal physical components involved with pruning entail the hand and forearm strength necessary to cut through the branches. Pruning is most often times performed with specially designed one-handed pruning shears with the exception of lopers that require both hands to cut thicker stems. The pruning shears used throughout industry is based on individual preference or is most often times distributed by the employer. The variety of pruning shears is designed for cutting efficiency as well as ergonomic purposes. Examples of shears are shown in Figure 3.

Figure 3. Pruning shears used in industry.

The random growth orientation of the branches for a particular trellised system causes the pruners to position themselves in awkward body postures. The workers constantly adjust their posture to account for the multidirectional growth of the stems. In addition, a major factor responsible for the overall posture of the worker is the height of the trellis system. The height of the trellis systems used throughout industry can range from an undersized vertical shoot positioned (VSP) 4x4 trellis approximately 61 cm in height in contrast with a significantly taller Lyre trellis approximately 122 cm in height. As an example, the VSP 4x4 will place the pruner in a squatting position with flexion of the back due to the relatively low height. In contrast, the Lyre system will situate the worker in an upright posture.

The pruning procedure will typically consist of using the right hand for the operation of the pruning shear while the left hand is used to clear the path for the right hand and remove branches that have been cut (see Figure 4).

Figure 4. Workers pruning vines.

It is clear that hand pruning of dormant vines requires considerable effort and time. Typically, this involves six-to-twelve week periods every year between the months of December and March. The pruning operation, among the various procedures involved in the production of wine, is one of the most expensive and labor consuming, and is exceeded in both respects only by the harvest process (Smart and Robinson, 1991; Tassie, 1992). Pruning has been previously shown to place workers at an increased risk of developing CTDs of the wrist (Roquelaure et al., 2002). Field visits by our group have shown, on average, that typical pruning work shifts are 8 hours with approximately 2330 cuts/hour.

Harvesting

Winegrape harvesting is a highly demanding activity in terms of energy requirements as well as biomechanical stress. The hand-harvest job cycle consists of cutting grapes from the vine and dropping them into a tub, stooping to move the tub to next position, and carrying the filled tub to dump the cut grapes into trailer-mounted bulk bins for transport. When cutting, the worker stands facing the vine, reaches in with the non-dominant hand, grasps a grape cluster, and cuts it free with a curved knife held in the dominant hand. The worker must constantly alter his/her body position, involving all joints of the body to see, reach, cut, and dispose of the 'grape clusters.' (See Figure 5).

Figure 5. Workers harvesting winegrape clusters.

As the worker moves along the vine to reach new clusters, he/she must either stoop to lift and place the tub in a new location, or push it with a foot to slide it along with a sideways leg movement. In the pre-intervention condition, when the tub is full (average = 25.8 kg./57 pounds, maximum =27 kg,/ 60 lb) the worker stoops to lift it, carries it to the tractor/trailer, and dumps the grapes into the bulk gondola at a height of 122 cm to 152.4 cm (4-5 ft.). Workers often carry tubs overhead and run with tubs, so that they are usually lowering the tubs from overhead or shoulder height positions to dump them into the gondola (Figure 6). Alternatively, workers may lift the tubs to the gondola from a carrying position at knuckle height. This often involves using a thigh to help accelerate the tub upward, changing the grip at mid-chest, and then combining arm, shoulder, back, and leg muscle effort in a coordinated thrust, propelling the grapes into the gondola. Workers are paid on a group incentive basis and move as fast as possible, filling a tub about every 2 minutes (30 per hour), or 210 per shift.

Figure 6. Workers dumping winegrape tubs into a gondola.

Project Significance and Approach

The University of California (UC) Agricultural Ergonomics Research Center (UC-AERC) is a multi-disciplinary team of UC researchers dedicated to application of ergonomics methods to the identification, analysis and prevention of MSDs in agricultural work. Winegrape vineyards initially were selected as an intervention site because they offer a stable workforce, are a large and fast growing sector of the California agricultural economy, and share many characteristics with other field agriculture commodities. The California winegrape vineyard industry had been expanding in capacity and acreage at a current rate exceeding 20,000 acres per year, ranking 2nd among all state agricultural commodities in the period of this project.

Project Goals

This project was a follow-up to a previous study of vineyard jobs, which found very high MSD and MSD symptom rates among winegrape vineyard workers and high ergonomics risk factor exposures. Together with cooperators, we determined to explore the effects of different commonly used grape trellis designs on risk factors for musculoskeletal disorder. Therefore, the main goal of the study is to improve research and industry understanding of ergonomic risk factors associated with each trellis system, and set forth suggested design parameters for reducing the negative impacts of each system on risk factor exposure. To achieve this goal, the study was designed to:

1. Identify and develop detailed ergonomics measurements of risk factors for musculoskeletal disorders and estimates of worker health outcomes for each of the most commonly used winegrape trellis systems.
2. Facilitate use of information about risk factors for musculoskeletal disorders associated with most commonly used winegrape trellis systems in trellis decision-making.
3. Develop practice and design parameters for reducing ergonomics risk factors associated with most used trellis systems.
4. Add to research knowledge about the association of specific agricultural workplace ergonomics risk factors and musculoskeletal disorders and their symptoms.

Project Cooperators

Four wine companies, one winegrape vineyard management company, and the UC Davis experimental vineyard formally cooperated in this project. In addition to vineyard managers, we considered farm workers as a cooperating target group as well. Farm workers participated in project management and in all field trials and field decision-making.

Participating operations were all mid-size by industry standards, and account for more than 300 permanent employees at the involved worksites and 1000 seasonal harvest workers. This industry is almost completely non-union in California, and there was no active union representation at any of the cooperator sites. The majority of workers in these operations are Spanish speaking, mostly from Mexico. They earn an average of $8-10 per hour. Most California farm workers consider Winegrape harvest work because it pays high wages for a relatively short timework period (8-10 weeks). Many seasonal workers can earn as much as 80% of their annual income in this period. All of these cooperators have active injury and illness prevention programs. Provision of worker's compensation insurance benefits is required in California.

Studies Conducted

Because the different trellis systems involved are spread across wide geographic areas and among multiple cooperators, we elected to focus our detailed ergonomics analyses on task simulations in quasi-laboratory conditions using the trellis structure developed cooperatively with the UC Davis Viticulture and Enology department. This decision effectively negated use of the Cooperative Demonstration Method in disseminating project information and results among growers and vineyard managers.

Hence, to achieve the project's primary specific aims, the project was divided into five main studies: 1) California Major Trellis Systems, 2) Ergonomic Evaluation: Pruning Simulation, 3) Ergonomic Evaluation: Harvest Simulation, 4) Ergonomic Evaluation: Field Observations, and 5) Field MSD Symptom Surveys. The rationale for these studies was that firstly, it is important to identify which trellis systems are the most popular in California (Study 1, Specific Aim #2). Secondly, since we are interested in identifying the potential effects of trellis systems on risk factors for MSDs during pruning and harvesting, it is important to conduct controlled studies looking at these effects (Studies 2&3: Specific Aims #3, 5-7). Thirdly, it was deemed important to conduct field observational studies to identify differences among trellis systems during actual pruning and harvesting work (Study 4: Specific Aims 3, 5-7). Lastly, in order to obtain field confirmation of the controlled studies, field surveys were conducted to obtain both symptom surveys and ergonomic risk factors evaluation by trellis type (Study 4, Specific Aims #4, 5-7). The following sections present each study in detail.

STUDY 1-CALIFORNIA MAJOR TRELLIS SYSTEMS

There are several vineyard trellis systems used throughout California and elsewhere. In order to help workers who perform hand pruning and harvesting tasks in California vineyards, it is important firstly to know which trellis systems are most often installed. However, there are no extensive data available, which categorize trellis systems by vineyard acreage. Consequently, a survey questionnaire (Figure 7) was sent out to all Viticulture and Enology farm advisors in the UC Davis Cooperative Extension program to obtain estimates of the most commonly used trellis systems. We also interviewed several large sellers of trellis system equipment to determine which trellises had the highest sales throughout California.

Using the interviews information coupled with the initial results of the survey and the existing limited literature, we identified seven trellis systems that encompass the majority of winegrape acreage throughout California. These systems are Traditional Single Curtain (California Sprawl); Vertical Shoot Positioned (VSP); Wye; Lyre; Scott-Henry; Smart-Henry; and Smart-Dyson. Of these systems, the VSP system seems to be the most widely used throughout California (>50,000 acres) for recent and new vineyards, followed by the Lyre (~10,000 acres) and Wye and Scott-Henry systems (~3,000 to 5,000 acres). Although the California Sprawl system covers a large area (>100,000 acres), mainly in the California Central Valley, this system is rarely used for new vineyards or for replanting existing ones, and is mostly machine-pruned and -harvested.

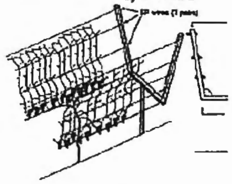
TRELLIS SURVEY

Region(s): ______________________________

Total number of vineyard acreage in your region(s): ______________

Below is a list of different trellis types. Please fill out the approximate percentage of vineyard acreage for each trellis if applicable. Also, can you please specify if the system is hand harvested (H) or mechanically harvested (M) by circling the correct letter:

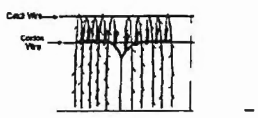
Lyre Trellis



Percentage: ______

H / M

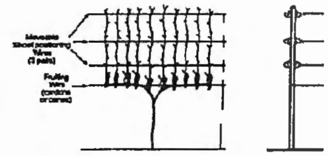
Traditional Single Curtain California Sprawl



Percentage: ______

H / M

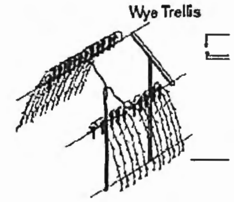
Vertically Shoot Positioned Trellis



Percentage: ______

H / M

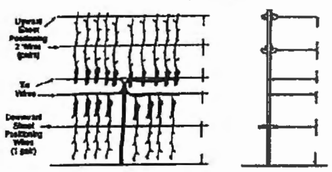
Wye Trellis



Percentage: ______

H / M

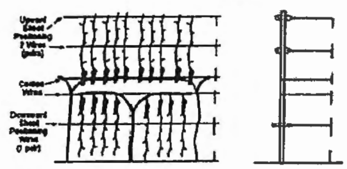
Scott-Henry Trellis



Percentage: ______

H / M

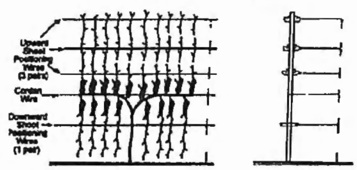
Smart-Henry Trellis



Percentage: ______

H / M

Smart-Dyson Trellis



Percentage: ______

H /

Any additional comments can be written on the back

Figure 7. Survey sent out to UC Farm Advisors to obtain estimates of trellis acreage.

There was also an indication that the Smart-Dyson system is gaining popularity in certain areas, especially in new vineyards. Another newly introduced system that also is gaining popularity was a lower version of the typical VSP systems, commonly referred to as the "VSP 4x4".

The observational/survey study described above revealed that a wide variety of trellis systems is used throughout the winegrape industry. However, five trellis systems seem to represent the majority of **hand-pruned** and **hand-harvested** trellises used throughout most of California. The identified trellis systems are: two Vertical Shoot Positioned (VSP) systems referred to as "VSP 4x4" and "VSP" for purposes of this research (each differing by height and separation distance between consecutive vines: regular VSP- 5' x 9', VSP 4x4 - 4' x 4'), Lyre, Scott Henry and Smart Dyson. Each of the five trellis systems is illustrated in Figure 8.

In general, the design characteristics of these systems vary significantly (Dokoozlian, 2000), which is expected to result in differences in workers exposure to MSD risk. Finding a trellis system that minimizes MSD risk factors would be beneficial in reducing the prevalence of MSDs in the winegrape industry. This study accomplished **Specific Aim #2**.

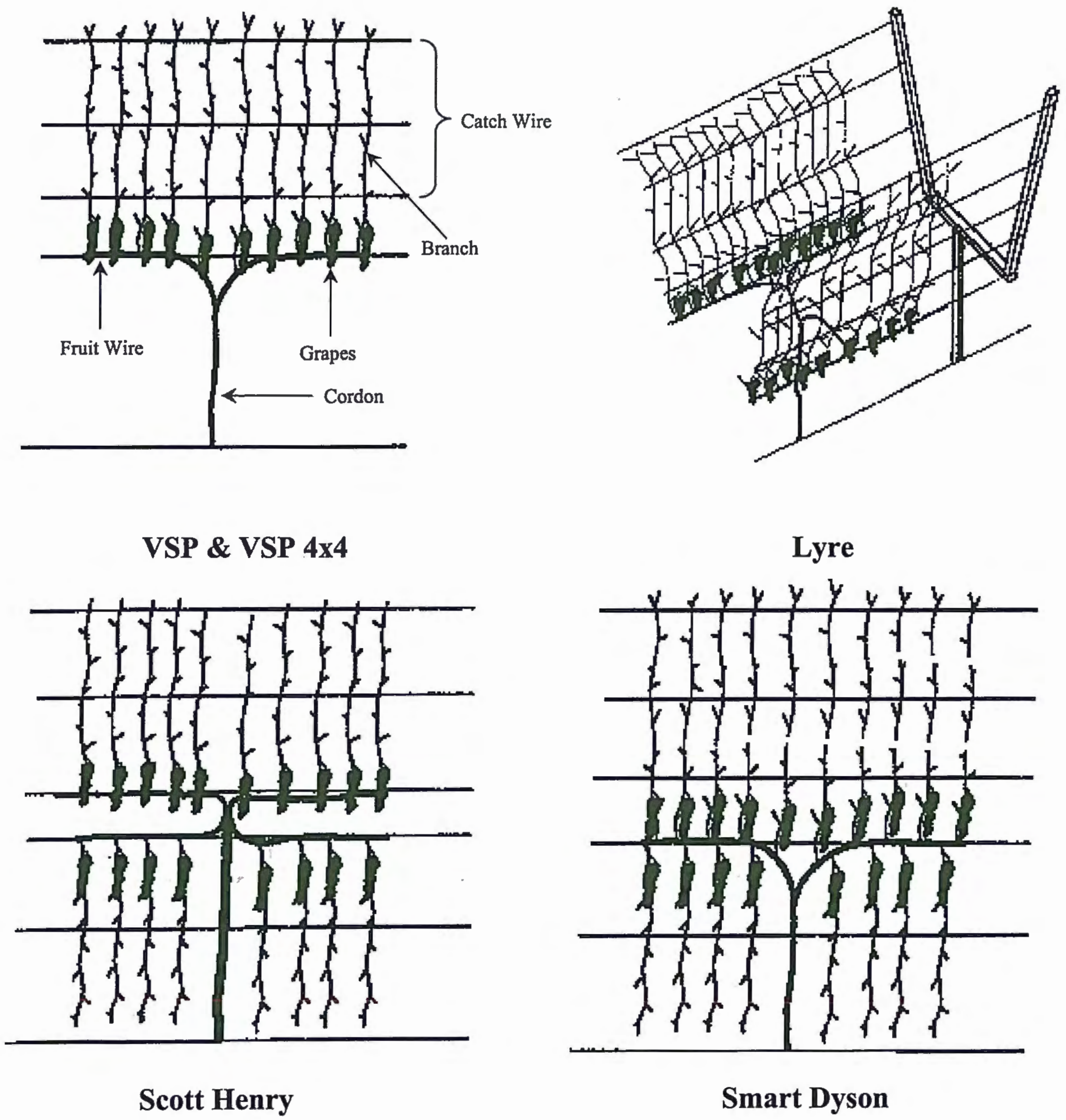


Figure 8. Trellis systems identified for this study. Adapted from Dokoozlian (2000).

STUDY 2-ERGONOMIC EVALUATION: PRUNING SIMULATION

OBJECTIVE

Although efforts have been made to develop alternatives to manual pruning, it is still considered the method of choice throughout the industry. The risks of developing MSDs are considerable due to the highly labor-intensive nature of the task. Very few systematic studies have been conducted concerning the quantitative assessment of the extent of MSD risk factors among various trellis systems. Therefore, the objective of this study is to quantitatively evaluate five commonly used trellis systems throughout the winegrape vineyard industry. This ergonomic evaluation will be based on the relative risks of developing MSDs to the wrist and the lower back while pruning, using a controlled simulation approach. The results of this study will assist vineyard proprietors to select an optimal trellis system concerning minimizing MSD risk exposure to the worker.

METHODOLOGY-PRUNING STUDY

Participants

Eleven healthy volunteers (10 males and 1 female) each with a minimum pruning experience of two years participated in this study. The volunteers were compensated workers at the UC Davis vineyards, which is administered by the campus Viticulture and Enology department. The mean age was 39 years (10.3 std. dev.), and mean stature was 169.5 cm (10.1 std. dev.). All participants were screened with regard to any current or recent MSD of the back, and upper extremities.

Apparatus

Five simulation trellis systems were constructed for this study: VSP 4x4, Smart Dyson, Scott Henry, VSP, and Lyre. The cutting heights were based on average vineyard standards and are as follows: 61.0 cm-VSP 4x4, 86.4 cm-Smart Dyson, 99.1 cm-Scott Henry, 106.7 cm-VSP, and 122 cm-Lyre. The row length for all trellis systems was approximately 9.1 m.

The WristSystem (Greenleaf Medical Systems, Inc., Palo Alto, CA), was used to capture the workers wrist joint motion. The WristSystem is a two-dimensional electrogoniometer that provides kinematic data of the wrist in the flexion/extension and radial/ulnar planes. The device consists of two gloves (one per hand) with cutouts for the digits and compartments for the transducers (see Figure 9). The Wrist System stores continuous data on portable data logger equipped with a SRAM card. Data collection frequency was set at 20 Hz. The device's accompanying Motion Analysis System (MAS) software was used to download the raw-data from the portable logger, and to convert the signals into angular positions.

Figure 9. The WristSystem shown on one of the study volunteers.

The Lumbar Motion Monitor (LMM) (Chattecx Corp., Hixon, TN) is an electrogoniometric device used to track the motion of the trunk in the three principal anatomical planes (sagittal, transverse and coronal). The device is secured on the volunteer's upper body through flexible harnesses. A wireless transmitter sends continuous data from the LMM to a laptop computer enabling the researcher to collect data without hindering the performance of the participant. Figure 10 shows a participant equipped with the LMM and WristSystem while performing a pruning trial.

Figure 10. A study participant performing the pruning task on the simulation trellis.

Experimental Design

The study was a one-way within-subject design with five levels (trellis systems, discussed above). The dependent variables were classified into two categories: 1) right and left mean wrist postures and mean velocities (flexion/extension, and radial/ulnar deviation), and 2) mean trunk postures and mean velocities (coronal, transverse, and sagittal angles). The pruning sequence for the trellis systems was randomly presented across all participants.

Approach Leading to Development of Experiment

Cordon Selection

With the identification of the trellis systems completed, the next objective involved the design parameters and characteristics for the simulation cordon and trellis systems. Pruning simulations were to be performed on mock trellis systems for a couple of reasons. First, simulation eliminates the interference with actual worker pruning activity. A significant amount of time is required for calibration, equipment set-up, data collection and equipment removal for each individual thus hindering worker productivity. Second, simulation provides a higher level of control over trellis design and pruning task variables.

A major issue concerning the design aspect was the identification of a substitute material for the replacement of actual branches. Options such as electrical wire fabricated to replicate branches, and stems gathered from random foliage were considered. Fortunately, branches were gathered from a single species of grapevine previously pruned from several vineyards belonging to the

UCD Viticulture and Enology department. This uniformity allowed the use of branches with similar characteristics (e.g., length, diameter) across different trellis systems. This will assure that any observed differences in the dependent measures will be due to the differences among the trellis characteristics (e.g., height).

The design and construction of the simulation cordons for each respective trellis system followed. A major challenge was to replicate the random growth of the branches that stemmed off each cordon arm. The design, construction and application of several model cordons were completed to select a most suitable design.

An initial attempt was made with a wooden frame. The length and height of each frame was approximated based on average cordon measurements and capacity requirements (average number of branches per cordon per type of trellis system). Floral aquafoam, used primarily for floral arrangements, is best characterized as a type of Styrofoam capable of absorbing moisture and securing stems in stationary positions. Three blocks of aquafoam (3" x 4" x 9") representing a single cordon arm were evenly placed onto nails (hammered from the underside of the top surface resulting in upward protruding mounts). Branches were placed randomly into the aquafoam to simulate a vine.

The aquafoam option would have been feasible with the exception of cost and time for the construction of each frame. A total of 15 frames would have to be constructed (three for each trellis system) for the simulation. Another major limitation was the difficulty in replicating the Smart Dyson and Scott Henry trellis systems, both of which have branches that shoot upward and downward. The difficulty was evident in the placement and attachment of the aquafoam onto the frame for the downward positioned stems. Nails were considered for securing each block of aquafoam; however, due to the mass of the block, the effect of gravity did not make this option viable. Alternative block fastening ideas were considered; however, the aquafoam was not able to maintain a rigid support on the downward positioned stems.

An attempt to fasten branches directly onto the trellis wires without the need of a cordon was made with releasable twist-ties. An exceptional feature of the twist-tie is the ability to undo and reuse the ties after each data collection trial. This option was not practical due to time constraints and the uniform positioning of the branches. The replacement and fastening of branches onto each wire after each data collection trial would be very tedious and inefficient. The uniform placement would cause the participant to maintain a stagnant wrist position throughout the entire pruning simulation resulting in a lack of wrist motion as observed in actual pruning situations.

The selected cordon system consisted of 4” x 9” rectangular blocks of floral Styrofoam. Each block was mounted with Velcro onto cardboard cutouts sized slightly larger than the blocks. Apertures were punctured through the corners of each cardboard piece for the fastening of twist-ties onto the trellis wires. Each trellis system was represented with three evenly spaced vines (foundation of cordon) that constitute the entire 10-yard section. The cordons for the Scott Henry and Smart Dyson systems comprised of eight blocks per cordon (four per cordon arm, 24 total); the VSP 4x4 and Lyre systems consisted of four blocks per cordon (two per cordon arm, 12 total); and the VSP comprised of six blocks per cordon (three per cordon arm, 18 total). An average branch density per trellis system was determined using video recordings of the pruning operations, and the information gathered during the initial field visits (data sheet for field visits shown in Appendix A). A standard of seven branches per block was approximated based on the average number of cuts completed by all participants per cordon for each respective trellis system. The total number of branches determined for each vine per trellis system are as follows: Regular VSP = 42, Lyre = 28, Scott Henry = 56, Smart Dyson = 56, and 4x4 VSP = 28. The variation in branch count is a consequence of the industrial densities that were observed for each respective system. The trellis/cordon systems that were constructed are shown in Figure 11.

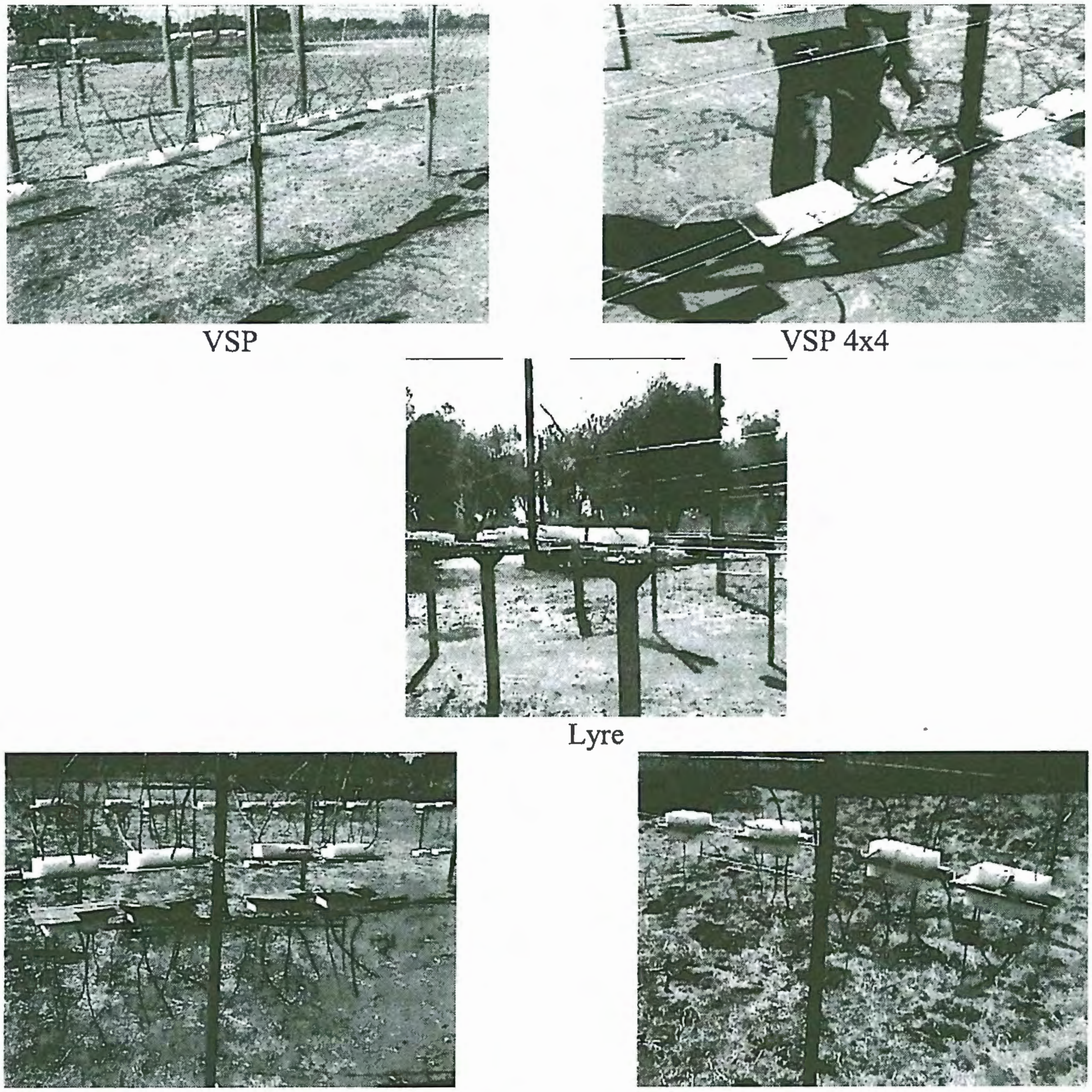


Figure 11. Trellis/cordon systems constructed for this study.

The branches were randomly placed into the Styrofoam to replicate the positioning of shoots on actual vines. Holes were punctured within the Styrofoam from the placement of the initial branch and were repeatedly used by replacing the stubs that remained from the previous pruning. Additional holes were created when the original holes were no longer capable of maintaining a firm foundation.

This option was most viable because the ability to replicate the random positioning of the branches created a highly realistic pruning scenario. The Floral Styrofoam is a resilient material capable of maintaining a firm grasp throughout repeated insertions. The fastening of the cardboard onto the trellis wire created stable pruning conditions across all trellis systems. In addition, the transition time required for branch replacement between participants was minimal.

Trellis Construction

The construction of each trellis system was completed with the assistance of staff members from the UCD Viticulture and Enology Department. The Trellis construction was initiated by placing end posts for each system into the ground by means of a tractor equipped with a post-pounding device. The insertion depth of each post was dependent on the design specifications for each trellis system. Lastly, the catch (single foliage support) wire and fruiting wires (double wire to support fruit) were installed for each system. A custom wire-tightening tool was used to set the preferred tension of each wire. The specific heights for each wire were determined by replicating the industrial measurements obtained for each system.

Experimental Procedure

Each participant agreed to participate in the study and signed an informed consent form (see Appendix B). The experiment began by finding the proper LMM and WristSystem sizes for each participant. There are several different glove sizes available for the wrist monitor. An initial estimate of the glove size was made by the experimenter and fitted onto each participant to determine an appropriate size. The LMM is available in small and large commercial sizes. A fairly accurate estimate on the proper LMM size was determined based on the height of the individual. In addition, prior experience and familiarity with the LMM was useful in the sizing process.

The second procedure was to individually calibrate the LMM and WristSystem systems. The calibration of the WristSystem system required each participant to wear the transducer gloves and position each wrist individually into the flexion/extension and ulnar/radial positions. Participants were instructed to deviate their wrist maximally in each of the four positions as the deviation angles were measured using a protractor. The calibration protocol for the WristSystem requested that participants place their wrists in a neutral posture followed by placement of the wrist in the flexion, extension, radial and ulnar position. The maximal angles in each respective position were measured and recorded into the WristSystem data-logging device. These angles represented boundary conditions, which allowed the WristSystem to determine angles during data collection.

The calibration of the LMM consisted of obtaining a baseline measurement while the LMM was held stationary in the carrying case. The carrying case maintained the alignment of the LMM in a neutral position with approximately 0° of displacement in the three principal planes of motion. Prior to data collection for each participant, the LMM software prompted the user to place the LMM in the carrying case for baseline collection purposes. Once the baselines were collected, the LMM was placed onto the participant.

The third procedure involved the placement of the WristSystem and LMM systems onto the participant. It was important to ensure that the battery for the WristSystem data-logger was fully charged, and the memory card was capable of storing two participants worth of data. The WristSystem data-logger was equipped with an adjustable strap that is tightened around the participants' waist. It was imperative that the wires from the transducer gloves, which connected to the data-logger, did not interfere with each participant during the pruning simulation. Therefore, as a precautionary measure, the extraneous wires were tucked into the waist straps of the WristSystem and LMM.

The LMM apparatus included a waist belt to stabilize the bottom portion of the LMM, a shoulder harness to maintain stability in the upper portion, and a waist strap used to fasten the transmitter and battery pack to the participant. The waist belt and shoulder harness were equipped with adjustable Velcro fasteners used to provide a snug fit and to prevent any movement of the LMM. The proper placement of the LMM onto the participant was concisely explained elsewhere (Marras et al., 1999). The LMM was fastened onto the shoulder harness followed by the attachment onto the waist belt. Once the proper adjustments were made, (i.e. proper placement of the LMM according to the specified anatomical landmarks) the transmitter was strapped onto the side of the participant.

With the participant properly fitted, data collection followed. Data were collected on two participants per day. Each participant was instructed to prune half of each row per trellis system and to perform the pruning task as they would normally. The row length was determined to be sufficient due to the repetitive nature of the task. In addition, each participant was instructed to stand in an upright posture prior to and after the pruning of all systems for neutral postural data (for normalization purposes) for the LMM. Set-up between participants was not necessary, and the replacement of the previously cut stems with new branches was completed before the arrival of the first participant each morning.

The data collection team consisted of three members each responsible for their respective duties. One person was responsible for LMM data collection, another for the WristSystem data collection and the final for videotaping.

The team leader was responsible for the LMM and informed the other members to initiate their respective responsibilities at the start of data collection. The operation of the LMM required experience and familiarity with the intricacies of the LMM software. The primary duty for LMM data collection focused on marking the start and end of each task. Two tasks were defined as pruning and neutral. Within the neutral task, a "before and after pruning" neutral tasks were collected.

The operation of the WristSystem system involved the activation and deactivation of the data logger to start and end each data collection session. The WristSystem system defined a session as a single data file, corresponding to the pruning of one type of trellis system, and was identified by the start and stop markers created for each collection session. Therefore, a total of five sessions (five trellis systems) per participant were defined and recorded for the WristSystem system. At the end of each data collection session, the collected data was uploaded into the laptop computer to clear the data logger memory card to ensure ample memory capacity for the next participant.

Video recordings for all participants pruning each system were obtained. The video recordings may be of assistance in identifying any unexplainable phenomena that was not noticed during the data collection sessions. In addition, further analyses utilizing observational methods are possible.

A subjective rating instrument was verbally administered at the completion of the last trellis system to capture participant's trellis preference. The participants were asked to rank the trellis systems in terms of difficulty pertaining to bodily discomfort from least to most difficult. The participants were told to respond assuming a typical eight-hour work-shift.

Data Analysis

For the wrist postural analyses, descriptive statistics were obtained for each trellis system for the right and left flexion/extension and radial/ulnar deviations. Similarly, for trunk postures, descriptive statistics were obtained for the coronal, sagittal and transverse angles.

Overall averages for the postural data in the flexion/extension and radial/ulnar planes were determined for both wrists. In addition, flexion, extension, radial and ulnar postures were analyzed separately. This was done due to the positive and negative values (i.e., extension and flexion) that may nullify the true postural representation. Similarly, overall (i.e., sagittal flexion/extension) and posture specific (i.e., sagittal extension) trunk averages were obtained. Frequency distributions centered on ranges of motion for the wrists and trunk in each respective plane of motion were created. The percent of time spent within a specified range was established for each principal plane of motion. The posture specific ranges of the wrist were based on the WristSystem software. The defined ranges represent a neutral range (range 2) and wrist postures beyond neutral (range 1, 3, 4) in both extremes (i.e. flexion and extension). The ranges for the wrist are defined as follows:

$1 = \theta \leq -15^{\circ}$ $\quad$ $2 = -15^{\circ} < \theta < 15^{\circ}$ $\quad$ $3 = 15^{\circ} \leq \theta < 30^{\circ}$ $\quad$ $4 = 30^{\circ} \leq \theta$

The posture specific ranges of the trunk were based on parameters established by Fathallah (Fathallah et al., 1998). The ranges for the trunk are defined as follows:

Sagittal Plane:

$1 = \theta < 0^\circ$ $2 = 0^\circ \leq \theta < 15^\circ$ $3 = 15^\circ \leq \theta < 30^\circ$ $4 = 30^\circ \leq \theta$

Coronal and Transverse Planes:

$1 = \theta < -15^\circ$ $2 = -15^\circ \leq \theta < 0^\circ$ $3 = 0^\circ \leq \theta < 15^\circ$ $4 = 15^\circ \leq \theta$

An average percent of time was obtained by taking the ratio of the number of data points that fell within the specified range and the overall number of collected data points per participant. The obtained ratios were collapsed across all participants resulting in average values per trellis system.

Analyses of variances (ANOVAs) were performed to determine statistical differences in wrist and trunk postures and velocities among trellis systems. The inconsistent DF error values associated with several of the independent ANOVAs were due to the elimination of participants due to outlying data points.

Correlation coefficients were determined to quantify the strength of association between the postural data of the trunk and wrist. Correlation coefficients were also determined for the relationship between the trunk and wrist postures and the cutting heights of each trellis system.

A non-parametric analysis was performed on the subjective ranking of the trellis systems. A Friedman ANOVA and Kendall Concordance Coefficient were determined with the rankings from nine out of the eleven participants. The responses from two participants were not complete.

RESULTS

The results of the data analysis will be presented in four separate sections: 1) wrists, 2) trunk, 3) correlation between the wrist and trunk postural data, correlation between the wrist/trunk postural data and pruning heights, and 4) subjective ranking of the trellis systems.

Wrist Analysis

The wrist analysis is divided into three sub-sections: 1) postural analysis, 2) postural frequency of occurrence and 3) velocity analysis.

Postural Analysis

Overall and posture specific averages were determined for both wrists. Extension and ulnar deviations are represented by positive values whereas flexion and radial deviations are represented by negative values. The descriptive statistics pertaining to the overall and unique postures are shown in Table 1 and Table 2, respectively.

Table 1. Descriptive statistics: Overall wrist posture.

	Trellis	Mean (°)	SD
Left Flexion/Extension	Lyre	15.54	11.24
	VSP	18.67	17.56
	Smart Dyson	16.68	16.83
	Scott Henry	18.86	12.24
	VSP 4x4	24.50	17.32
Left Radial/Ulnar	Lyre	11.46	23.47
	VSP	4.96	18.24
	Smart Dyson	11.76	22.70
	Scott Henry	11.18	22.57
	VSP 4x4	1.92	24.23
Right Flexion/Extension	Lyre	2.62	9.20
	VSP	4.55	10.80
	Smart Dyson	4.48	12.68
	Scott Henry	10.23	12.60
	VSP 4x4	0.22	9.92
Right Radial/Ulnar	Lyre	0.51	6.34
	VSP	2.33	7.20
	Smart Dyson	-1.60	9.06
	Scott Henry	-0.24	9.99
	VSP 4x4	-0.36	6.15

(+) = Extension and ulnar deviation (-) = Flexion and radial deviation

Table 2. Descriptive statistics: Specific wrist postures.

	Trellis	Mean (°)	SD
Left Flexion	Lyre	-12.61	10.07
	VSP	-7.17	4.26
	Smart Dyson	-4.49	3.47
	Scott Henry	-7.06	6.25
	VSP 4x4	-12.04	6.87
Left Extension	Lyre	18.69	10.55
	VSP	22.97	14.56
	Smart Dyson	19.73	14.28
	Scott Henry	21.61	12.03
	VSP 4x4	29.68	7.91
Left Radial	Lyre	-7.84	5.22
	VSP	-8.68	6.53
	Smart Dyson	-9.71	6.50
	Scott Henry	-9.16	5.57
	VSP 4x4	-17.88	13.16
Left Ulnar	Lyre	27.65	17.84
	VSP	14.71	12.96
	Smart Dyson	28.77	18.92
	Scott Henry	27.63	18.38
	VSP 4x4	17.38	17.35
Right Flexion	Lyre	-11.73	6.70
	VSP	-8.44	5.15
	Smart Dyson	-9.92	7.95
	Scott Henry	-9.74	7.69
	VSP 4x4	-12.42	6.42
Right Extension	Lyre	13.52	7.69
	VSP	12.87	8.35
	Smart Dyson	13.28	7.24
	Scott Henry	17.35	8.25
	VSP 4x4	13.01	5.62
Right Radial	Lyre	-7.60	5.62
	VSP	-5.10	3.47
	Smart Dyson	-8.69	6.32
	Scott Henry	-7.46	7.19
	VSP 4x4	-5.39	3.03
Right Ulnar	Lyre	7.00	6.50
	VSP	7.29	5.98
	Smart Dyson	7.82	6.20
	Scott Henry	7.16	7.03
	VSP 4x4	6.40	4.12

Table 3 shows the ANOVA results for the overall and posture specific averages. The overall conditions resulted in significant differences among the five trellis systems. Differences were noticed in the flexion/extension and radial/ulnar planes for the left wrist and in the flexion/extension plane for the right wrist. Significance was also noticed for the left extension and left ulnar posture specific conditions.

Table 3. ANOVA results for wrist posture of right and left hands.

Overall	DF Effect	MS Effect	DF Error	MS Error	F	p-level
Left Flexion/Extension	4	130.797	40	59.496	2.198	0.087*
Left Radial/Ulnar	4	205.324	36	61.275	3.351	0.020**
Right Flexion/Extension	4	136.589	36	59.296	2.304	0.077*
Right Radial/Ulnar	4	22.919	40	19.634	1.167	0.340
Posture Specific						
Left Flexion	4	23.285	8	17.784	1.309	0.345
Left Extension	4	160.382	36	37.013	4.333	0.006**
Left Ulnar	4	227.691	20	91.267	2.495	0.076*
Left Radial	4	69.107	16	30.326	2.279	0.106
Right Flexion	4	23.321	32	17.788	1.311	0.287
Right Extension	4	35.589	36	25.981	1.370	0.264
Right Ulnar	4	4.058	20	4.775	0.850	0.510
Right Radial	4	21.088	24	14.007	1.506	0.232

* Significant at $p < 0.1$
** Significant at $p < 0.05$

Figure 12 through Figure 14 show the overall average of the left wrist in the flexion/extension and radial/ulnar planes and the right wrist in the flexion/extension plane, respectively. Figure 15 and Figure 16 show the posture specific averages of the left wrist in the extension and ulnar positions, respectively. Newman-Keuls comparisons were completed at the $p<0.05$ level for the left radial/ulnar condition and for the left extension condition. LSD comparisons were completed for the left and right flexion/extension conditions and the left ulnar condition. Dissimilar letters as shown on each figure indicate significant differences between the trellis systems.

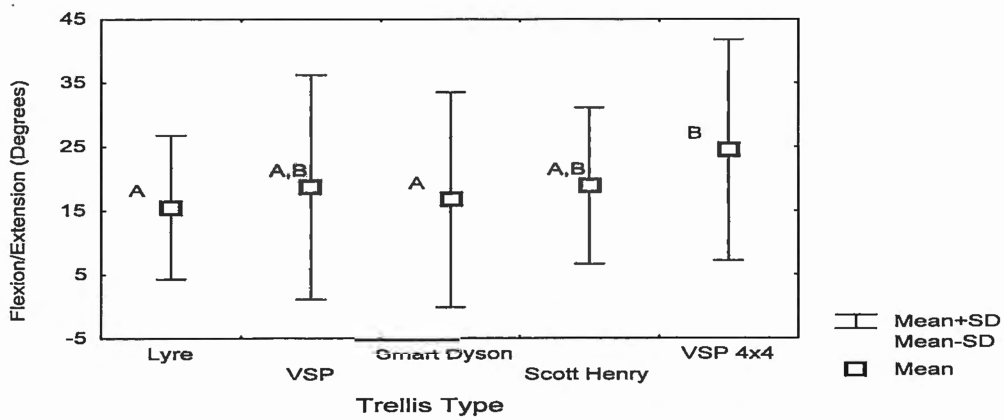


Figure 12. Average flexion/extension of left wrist.

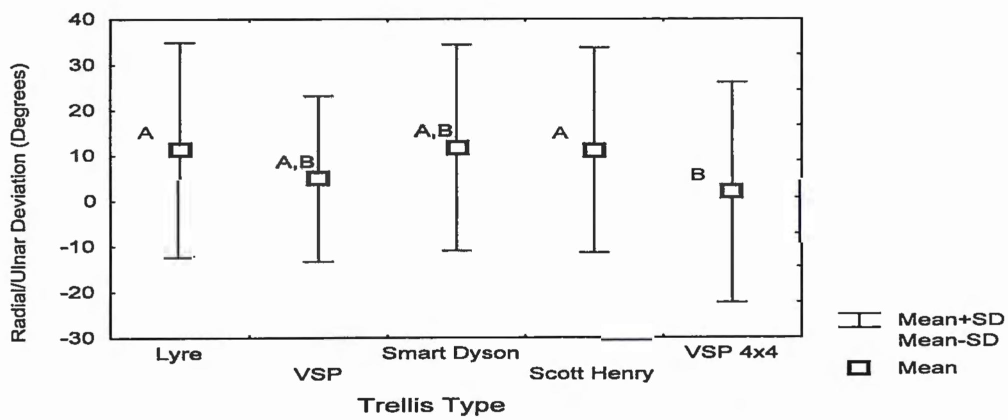


Figure 13. Average radial/ulnar deviation of left wrist.

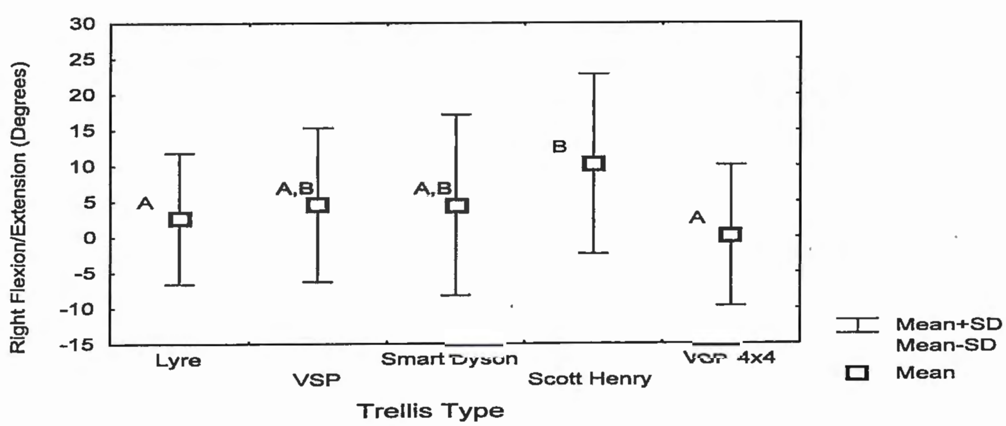


Figure 14. Average flexion/extension of right wrist.

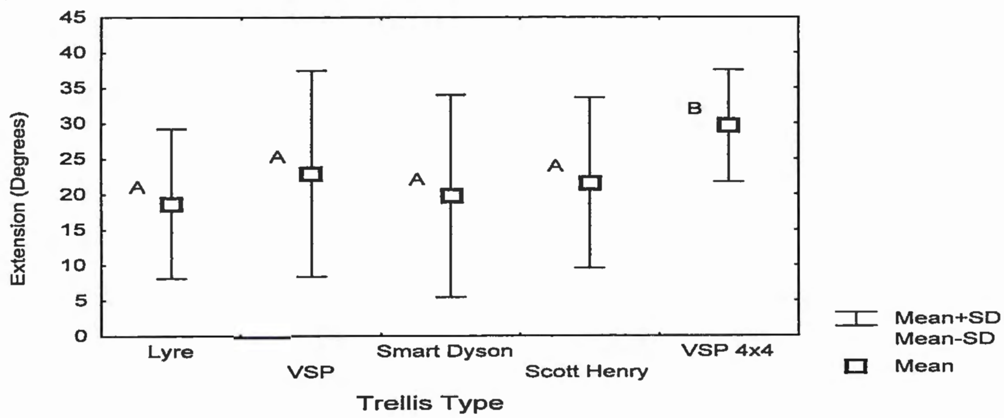


Figure 15. Average extension of left wrist.

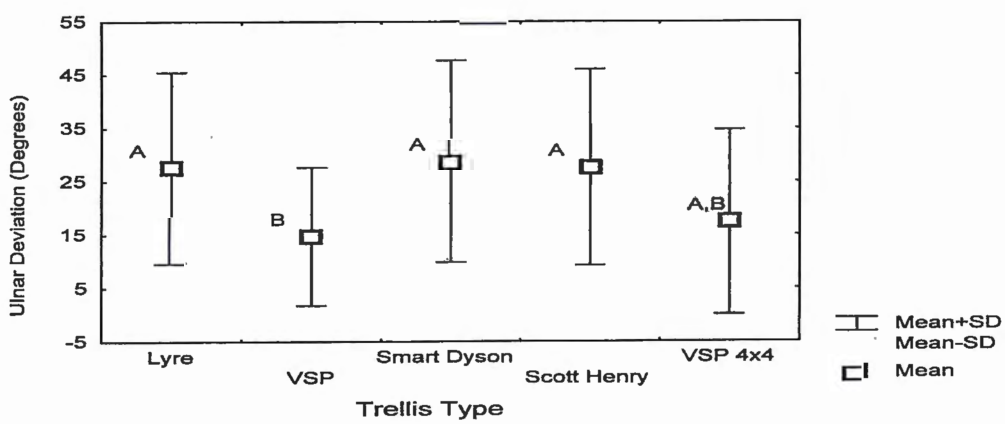


Figure 16. Average ulnar deviation of left wrist.

Postural Frequency of Occurrence

The percent of time spent within a specified range was established for each principal plane of motion as shown in Table 4. Graphical representations are shown in Figure 17 through Figure 20. Extension and ulnar deviations are represented by positive values whereas flexion and radial deviations are represented by negative values.

Table 4. Average percent of time spent in specified ranges.

	Range	Lyre	VSP	Smart Dyson	Scott Henry	VSP 4x4
Left Flexion/Extension	1	3.1	0.3	1.5	2.5	9.1
	2	49.0	51.2	50.2	42.2	13.7
	3	27.4	18.4	24.1	31.2	35.1
	4	20.5	30.1	24.2	24.1	42.1
Left Radial/Ulnar	1	3.4	6.7	13.6	6.1	19.3
	2	56.3	66.3	44.2	52.5	50.4
	3	10.0	12.4	8.9	12.2	12.5
	4	30.3	14.5	33.3	29.2	17.8
Right Flexion/Extension	1	15.6	9.2	12.8	6.5	17.1
	2	63.7	68.4	62.6	56.4	65.0
	3	13.2	12.6	15.7	19.8	12.5
	4	7.4	9.7	8.8	17.2	5.4
Right Radial/Ulnar	1	5.8	3.7	13.4	8.8	6.0
	2	85.8	87.0	78.3	81.3	89.6
	3	7.9	8.9	8.0	8.9	4.3
	4	0.4	0.4	0.4	0.9	0.1

The ranges listed in Table 4 and Table 5 are defined as follows:

$1 = \theta \leq -15^{\circ}$ $2 = -15^{\circ} < \theta < 15^{\circ}$ $3 = 15^{\circ} \leq \theta < 30^{\circ}$ $4 = 30^{\circ} \leq \theta$

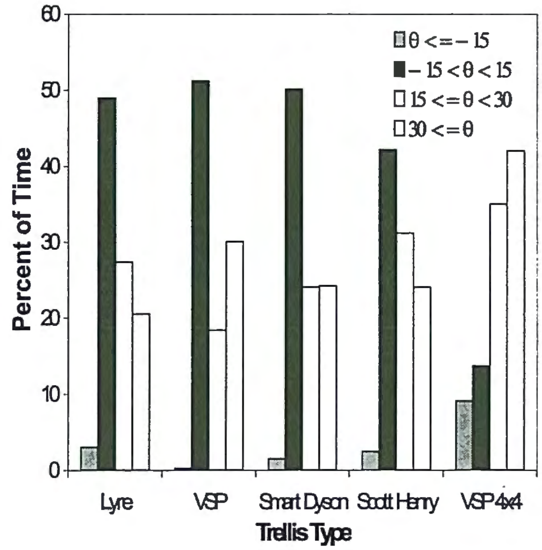


Figure 17. Percent of time spent in flexion/extension of left wrist.

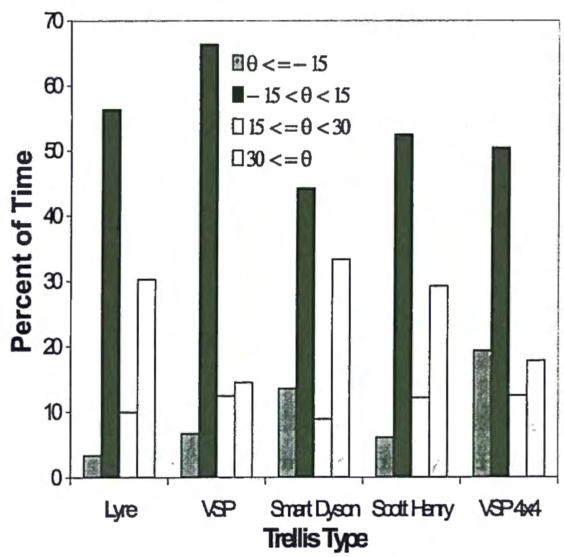


Figure 18 Percent of time spent in flexion/extension of right wrist.

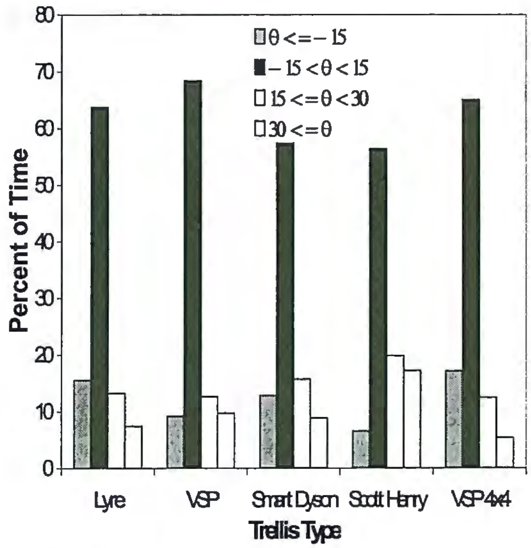


Figure 19. Percent of time spent in radial/ulnar deviation of left wrist.

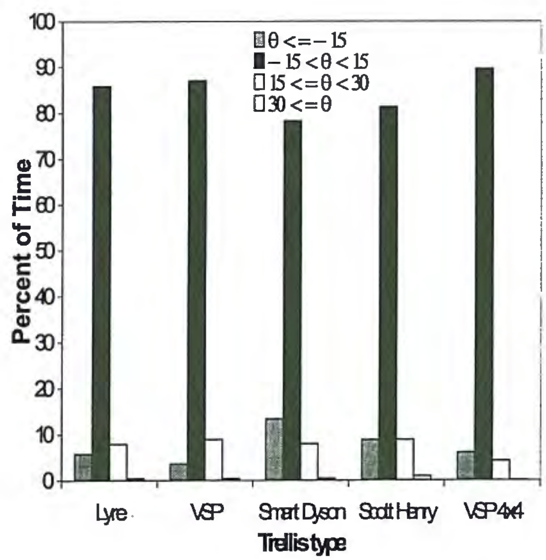


Figure 20. Percent of time spent in radial/ulnar deviation of right wrist.

Results from the ANOVA performed across all trellis systems for each defined range of motion are presented in Table 5. Significant differences were noticed for ranges 2 and 4 for the flexion/extension of the left wrist.

Table 5. ANOVA results for percent of time in specified wrist postures.

	Range	DF Effect	MS Effect	DF Error	MS Error	F	p-level
Left Flexion/Extension	1	4	128.728	40	154.361	0.834	0.512
	2	4	2743.308	40	361.312	7.593	0.000**
	3	4	454.346	40	301.181	1.509	0.218
	4	4	793.074	40	220.176	3.602	0.013*
Left Radial/Ulnar	1	4	421.400	36	432.006	0.975	0.433
	2	4	671.093	36	756.564	0.887	0.482
	3	4	27.327	36	75.239	0.363	0.833
	4	4	694.023	36	383.433	1.810	0.148
Right Flexion/Extension	1	4	193.103	36	169.085	1.142	0.352
	2	4	193.616	36	219.414	0.882	0.484
	3	4	96.309	36	71.365	1.350	0.271
	4	4	203.706	36	106.868	1.906	0.131
Right Radial/Ulnar	1	4	154.753	40	146.453	1.057	0.390
	2	4	227.732	40	159.649	1.426	0.243
	3	4	40.580	40	61.259	0.662	0.622
	4	4	0.971	40	0.602	1.612	0.190

* Significant at $p < 0.05$
** Significant at $p < 0.01$

Figure 21 and Figure 22 show the average percent of time differences in the left flexion/extension plane across all trellis systems for postures within the 2 and 4 ranges, respectively. The *post-hoc* comparisons (LSD) were completed and are denoted by the dissimilar letters indicating significant differences between the trellis systems.

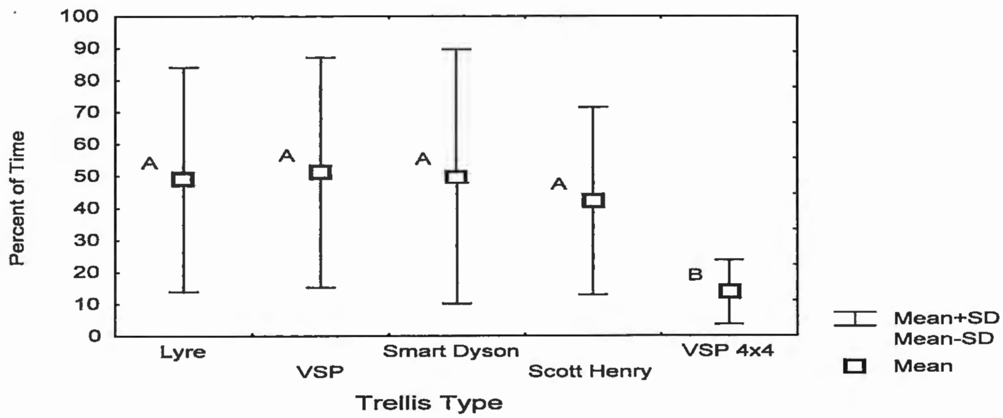


Figure 21. Average percent of time spent in left flexion/extension plane ($-15^{\circ} < \theta < 15^{\circ}$).

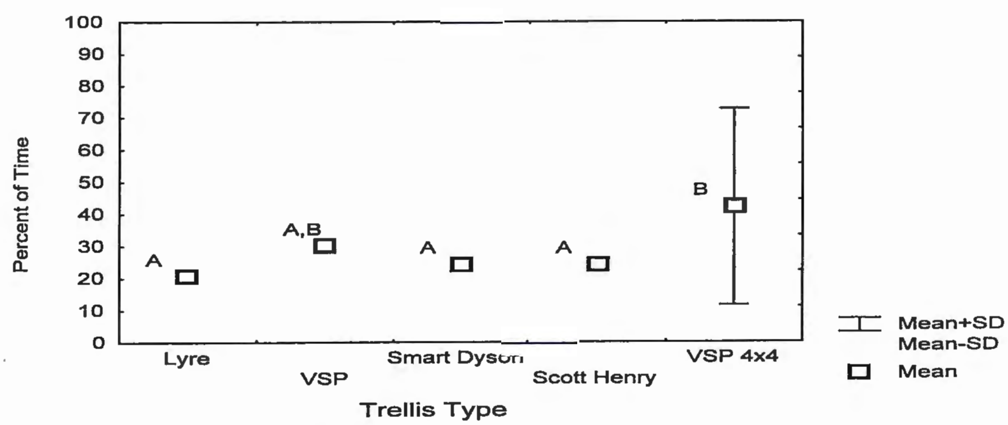


Figure 22. Average percent of time spent in left flexion/extension plane ($30^{\circ} \leq \theta$).

Velocity Analysis

Descriptive statistics for posture specific wrist velocities are shown in Table 6.

Table 6. Descriptive statistics: Wrist velocity.

	Trellis	Mean (deg/sec)	SD
Left Flexion	Lyre	-6.28	3.09
	VSP	-5.77	3.61
	Smart Dyson	-4.52	2.70
	Scott Henry	-6.55	4.12
	VSP 4x4	-4.91	2.77
Left Extension	Lyre	6.19	4.00
	VSP	5.27	2.95
	Smart Dyson	5.25	3.15
	Scott Henry	7.03	3.31
	VSP 4x4	5.95	2.08
Left Radial	Lyre	-4.87	4.97
	VSP	-3.75	2.96
	Smart Dyson	-5.1	7.18
	Scott Henry	-5.05	6.34
	VSP 4x4	-4.81	4.91
Left Ulnar	Lyre	5.50	5.85
	VSP	4.75	5.41
	Smart Dyson	4.51	5.03
	Scott Henry	4.67	6.23
	VSP 4x4	5.95	6.09
Right Flexion	Lyre	-8.21	3.42
	VSP	-7.38	3.81
	Smart Dyson	-6.98	3.14
	Scott Henry	-7.89	2.17
	VSP 4x4	-8.35	2.82
Right Extension	Lyre	8.16	2.68
	VSP	7.23	3.86
	Smart Dyson	7.24	3.01
	Scott Henry	7.49	1.83
	VSP 4x4	8.08	3.51
Right Radial	Lyre	-3.00	2.43
	VSP	-2.61	2.13
	Smart Dyson	-2.50	2.33
	Scott Henry	-2.85	2.17
	VSP 4x4	-2.49	1.80
Right Ulnar	Lyre	3.11	2.52
	VSP	2.47	2.03
	Smart Dyson	2.51	2.41
	Scott Henry	2.97	2.35
	VSP 4x4	2.83	1.96

An ANOVA was performed on the velocity data for the posture specific conditions. There were no significant differences across all conditions. The results are shown in Table 7.

Table 7: ANOVA results for wrist velocities.

	DF Effect	MS Effect	DF Error	MS Error	F	p-level
Left Extension	4	5.976	40	3.728	1.603	0.192
Left Flexion	4	8.349	40	4.727	1.766	0.155
Left Radial	4	3.062	36	6.258	0.489	0.744
Left Ulnar	4	4.188	40	7.625	0.549	0.701
Right Extension	4	2.036	36	3.380	0.603	0.663
Right Flexion	4	3.632	40	4.337	0.838	0.510
Right Radial	4	0.565	40	1.003	0.564	0.690
Right Ulnar	4	0.868	40	1.343	0.646	0.633

Trunk Analysis

The trunk analysis is divided into three sub-sections: 1) postural analysis, 2) postural frequency of occurrence and 3) velocity analysis.

Postural Analysis

Averages for the overall trunk position in the three principal planes of motion (coronal, sagittal and transverse) and posture specific trunk positions (i.e. sagittal flexion, sagittal extension) were determined for each trellis system. Descriptive statistics for the overall and posture specific trunk postures are shown in Table 8 and Table 9, respectively.

Negative values indicate sagittal extension and movement to the individuals left for the coronal and transverse planes.

Table 8. Descriptive statistics: Overall trunk postures.

	Trellis	Mean (°)	SD
Coronal	Lyre	-2.62	3.56
	VSP	1.58	4.13
	Smart Dyson	-3.63	3.02
	Scott Henry	-4.37	4.66
	VSP 4x4	2.27	5.81
Sagittal	Lyre	-3.94	5.93
	VSP	9.35	7.44
	Smart Dyson	14.25	8.73
	Scott Henry	20.04	9.42
	VSP 4x4	44.59	14.16
Lateral	Lyre	-0.61	3.85
	VSP	-0.64	2.56
	Smart Dyson	-0.74	4.08
	Scott Henry	-0.16	4.37
	VSP 4x4	-0.79	3.72

Table 9. Descriptive statistics: Specific trunk postures.

	Trellis	Means (°)	SD
Coronal Right	Lyre	2.93	2.03
	VSP	4.63	2.96
	Smart Dyson	4.67	2.22
	Scott Henry	3.50	2.46
	VSP 4x4	5.54	4.55
Coronal Left	Lyre	-5.24	1.98
	VSP	-3.98	1.62
	Smart Dyson	-7.90	2.17
	Scott Henry	-8.02	3.63
	VSP 4x4	-4.06	2.33
Sagittal Flexion	Lyre	3.94	5.10
	VSP	9.71	7.08
	Smart Dyson	16.19	7.41
	Scott Henry	24.24	7.96
	VSP 4x4	44.62	14.15
Sagittal Extension	Lyre	-5.67	4.70
	VSP	-1.21	1.07
	Smart Dyson	-1.95	1.48
	Scott Henry	-1.95	1.43
	VSP 4x4	-0.47	0.30
Transvere Right	Lyre	3.57	1.74
	VSP	2.87	0.99
	Smart Dyson	2.89	1.51
	Scott Henry	3.47	2.04
	VSP 4x4	2.26	1.91
Transverse Left	Lyre	-4.03	2.29
	VSP	-3.14	1.72
	Smart Dyson	-3.56	2.69
	Scott Henry	-3.50	2.64
	VSP 4x4	-2.69	1.91

Table 10 shows the ANOVA results for the overall and posture specific averages. The overall and posture specific conditions resulted in significant differences among the five trellis systems. Differences were noticed in the overall coronal and sagittal planes and in the coronal right and left, sagittal flexion and transverse right conditions. An analysis on the sagittal extension condition was not performed due to the lack of participants that experienced trunk extension. This lack of data affected the power of the ANOVA.

Table 10. ANOVA results for trunk postures.

Overall	DF Effect	MS Effect	DF Error	MS Error	F	p-level
Coronal	4	103.400	40	10.759	9.611	0.000**
Sagittal	4	3505.871	40	26.821	130.713	0.000**
Transverse	4	0.677	40	5.419	0.125	0.973
Posture Specific						
Coronal Right	4	11.816	40	4.734	2.496	0.058*
Coronal Left	4	43.957	40	4.339	10.130	0.000**
Sagittal Flexion	4	2756.503	40	39.602	69.605	0.000**
Transverse Right	4	3.589	36	1.424	2.520	0.058*
Transverse Left	4	2.759	40	2.508	1.100	0.370

* Significant at p < 0.1
** Significant at p < 0.01

Figure 23 and Figure 24 show the overall averages of the coronal and sagittal trunk postures, respectively. Figure 25 through Figure 28 show the posture specific averages for the trunk in the coronal right and left, sagittal flexion and transverse right conditions, respectively. Newman-Keuls comparisons were completed at the $p<0.05$ level for the overall coronal and sagittal postures. LSD comparisons were completed for the right and left coronal and right transverse conditions. Dissimilar letters as shown on each figure indicate significant differences between the trellis systems.

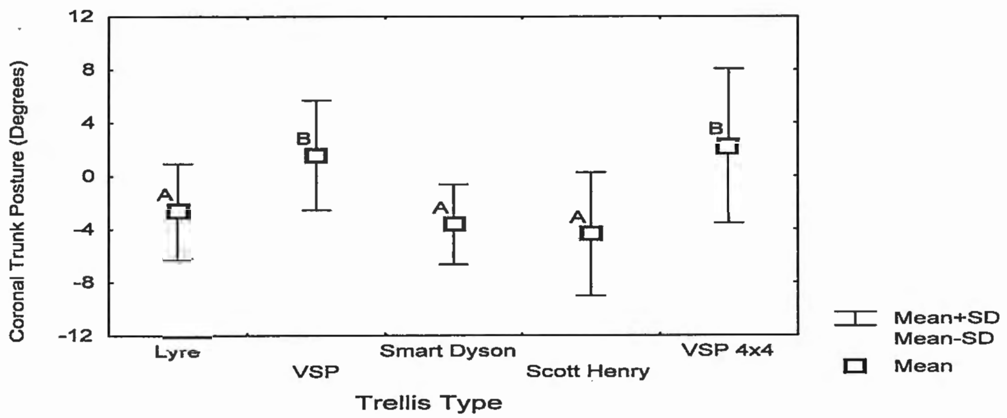


Figure 23. Average trunk posture in coronal plane.

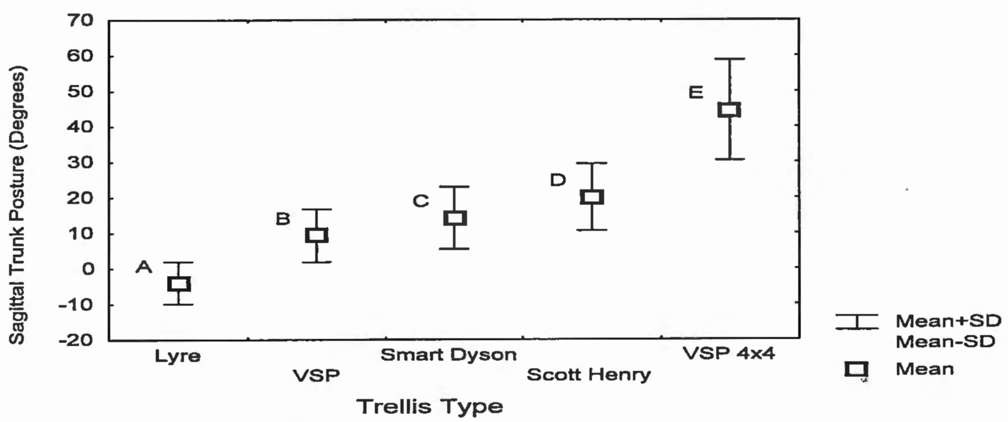


Figure 24. Average trunk posture in sagittal plane.

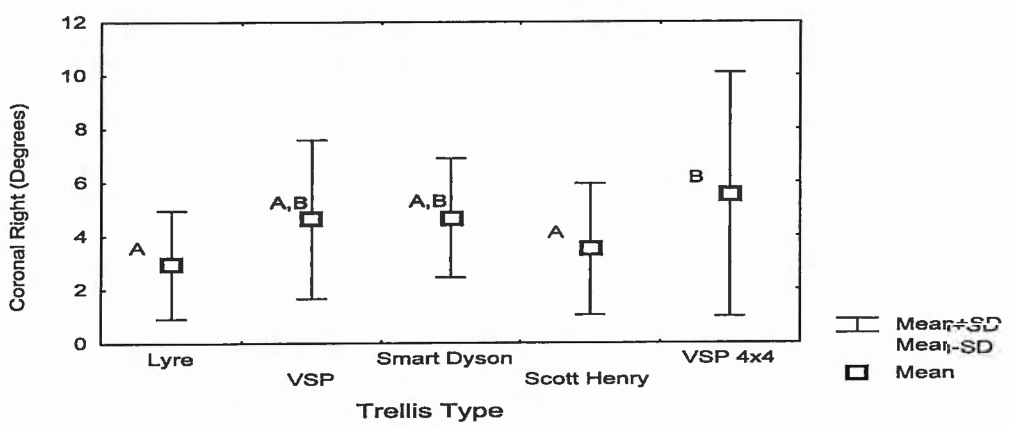


Figure 25. Average trunk posture in coronal right position.

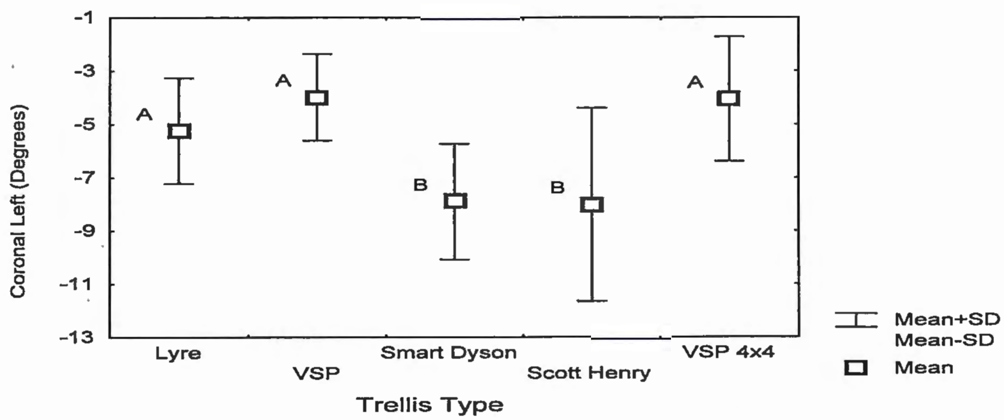


Figure 26. Average trunk posture in coronal left position.

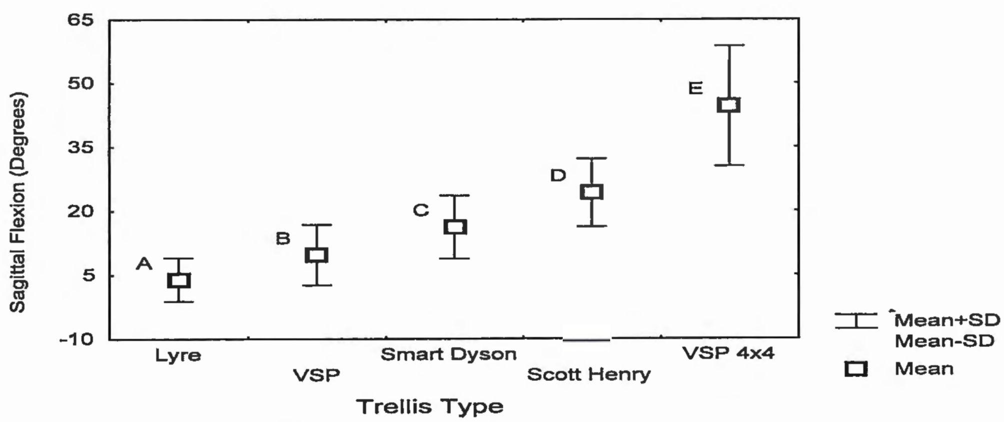


Figure 27. Average trunk posture in sagittal flexion.

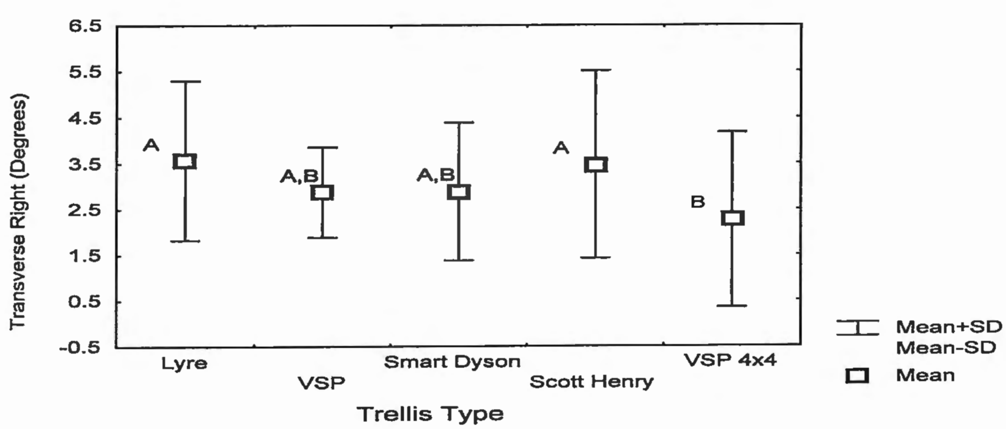


Figure 28. Average trunk posture in transverse right position.

Postural Frequency of Occurrence

The percent of time spent within a specified range was established for each principal plane of motion as shown in Table 11. The same method used to determine the percent of time for the wrist postures was used. Graphical representations are shown in Figure 29 through Figure 31. As mentioned previously, negative values indicate sagittal extension and movement to the individuals left for the coronal and transverse planes.

Table 11. Average percent of time in specified trunk postures.

	Range	Lyre	VSP	Smart Dyson	Scott Henry	VSP 4x4
Coronal	1	1.6	0.8	0.2	11.8	1.1
	2	66.7	37.2	59.3	58.1	40.3
	3	31.3	58.4	31.0	28.7	52.6
	4	0.4	3.5	1.4	1.5	6.1
Sagittal	1	67.3	6.0	12.7	17.1	0.1
	2	32.5	73.2	52.1	38.7	4.5
	3	0.1	18.5	19.1	13.2	14.8
	4	0.1	2.3	16.2	31.1	80.5
Transverse	1	1.0	0.6	1.7	1.6	0.0
	2	52.4	57.8	51.5	49.4	61.3
	3	46.2	41.5	46.4	47.6	38.5
	4	0.4	0.0	0.4	1.4	0.2

The ranges listed in Table 11 and Table 12 are defined as follows:

Sagittal Plane:

$1 = \theta < 0^\circ$ $2 = 0^\circ \leq \theta < 15^\circ$ $3 = 15^\circ \leq \theta < 30^\circ$ $4 = 30^\circ \leq \theta$

Coronal and Transverse Planes:

$1 = \theta < -15^\circ$ $2 = -15^\circ \leq \theta < 0^\circ$ $3 = 0^\circ \leq \theta < 15^\circ$ $4 = 15^\circ \leq \theta$

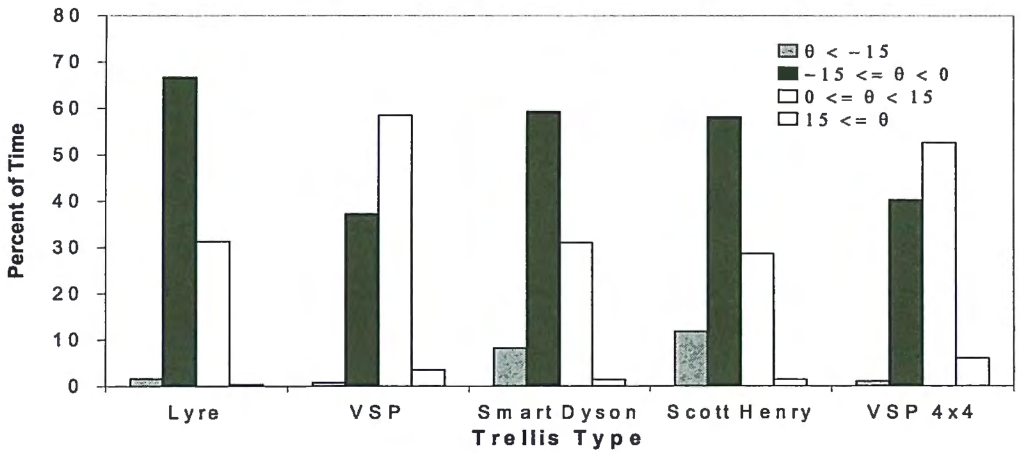


Figure 29. Percent of time in coronal plane.

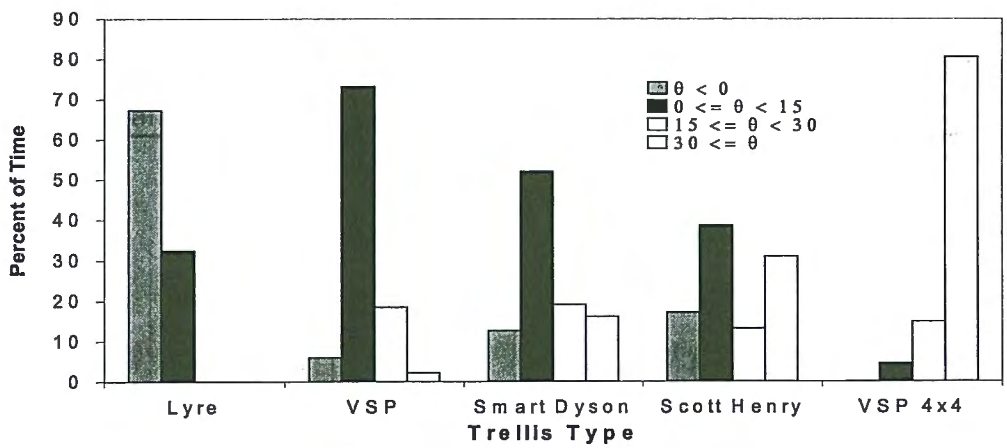


Figure 30. Percent of time in sagittal plane.

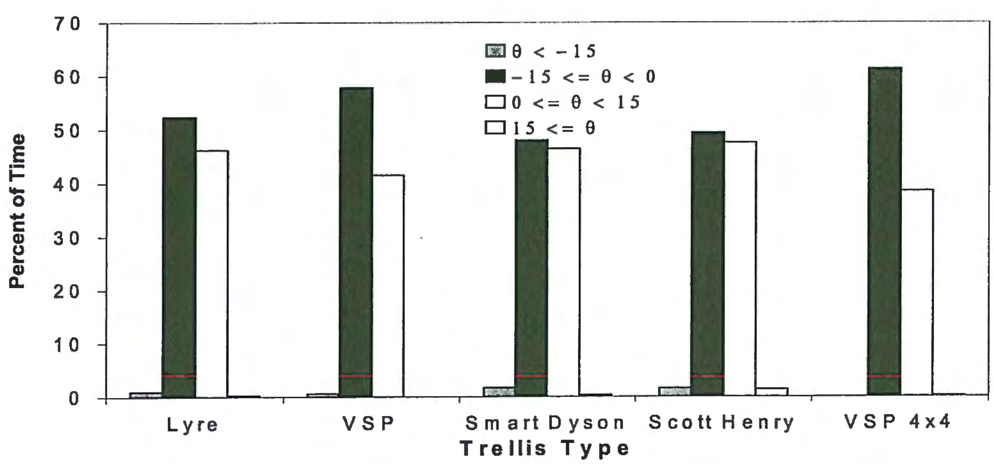


Figure 31. Percent of time in transverse plane.

Results from the ANOVA performed across all trellis systems for each defined range of motion are presented in Table 12. Significant differences were noticed for the coronal (range: 1, 2, 3) and sagittal (range: 1, 2, 4) planes.

Table 12. ANOVA results for trunk percent of time.

	Range	DF Effect	MS Effect	DF Error	MS Error	F	p-level
Coronal	1	4	0.028	40	0.006	4.537	0.004*
	2	4	0.182	40	0.028	6.493	0.000*
	3	4	0.215	40	0.033	6.585	0.000*
	4	4	0.006	40	0.009	0.613	0.656
Sagittal	1	4	0.795	40	0.028	28.047	0.000*
	2	4	0.705	40	0.062	11.339	0.000*
	3	4	0.065	40	0.037	1.767	0.155
	4	4	1.191	40	0.017	71.346	0.000*
Transverse	1	4	0.001	40	0.001	1.061	0.388
	2	4	0.027	40	0.034	0.793	0.537
	3	4	0.017	40	0.036	0.464	0.761
	4	4	0.000	40	0.000	1.810	0.146

* Significant at $p < 0.01$

Figure 32 through Figure 34 show the percent of time differences in the coronal plane across all trellis systems for postures within the 1, 2 and 3 ranges, respectively. Figure 35 through Figure 37 show the percent of time differences in the sagittal plane across all trellis systems for postures within the 1, 2 and 4 ranges, respectively. Newman-Keuls comparisons were completed at the $p<0.05$ level for all conditions. Dissimilar letters as shown on each figure indicate significant differences between the trellis systems.

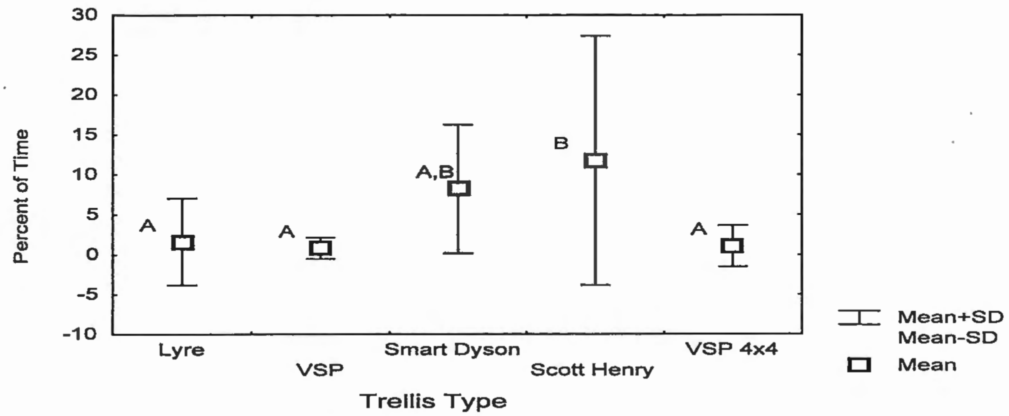


Figure 32. Average percent of time spent in coronal plane ($\theta < -15^{o}$).

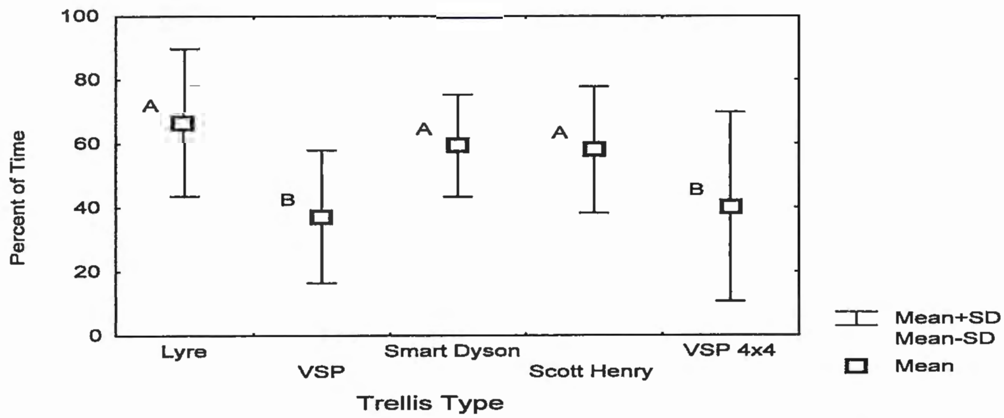


Figure 33. Average percent of time spent in coronal plane ($-15^{o} \leq \theta < 0^{o}$).

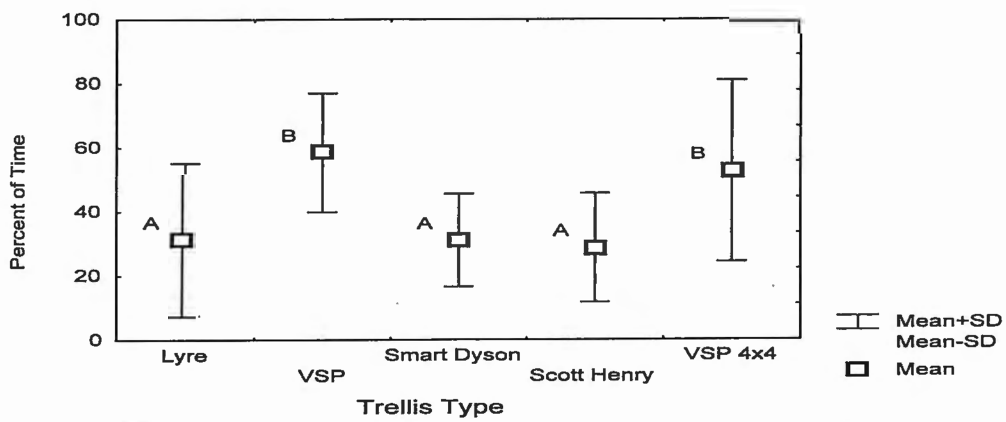


Figure 34. Average percent of time spent in coronal plane ($0^{o} \leq \theta < 15^{o}$).

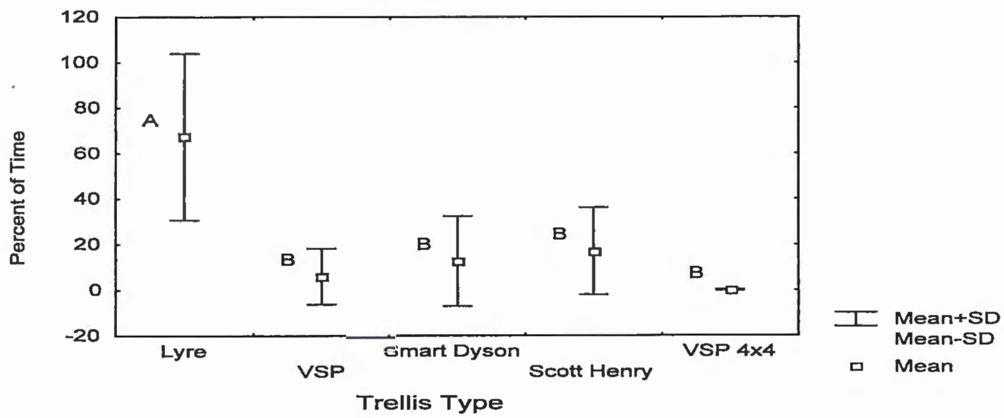


Figure 35. Average percent of time spent in sagittal plane ($\theta < 0°$).

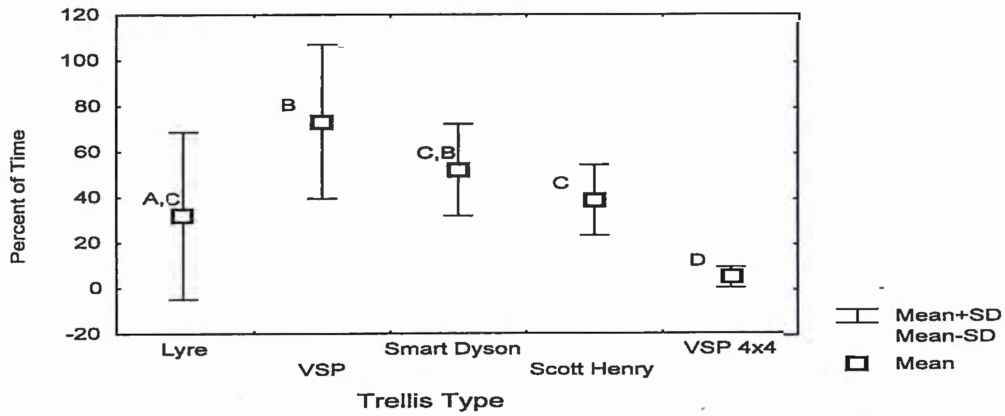


Figure 36. Average percent of time spent in sagittal plane ($0° \leq \theta < 15°$).

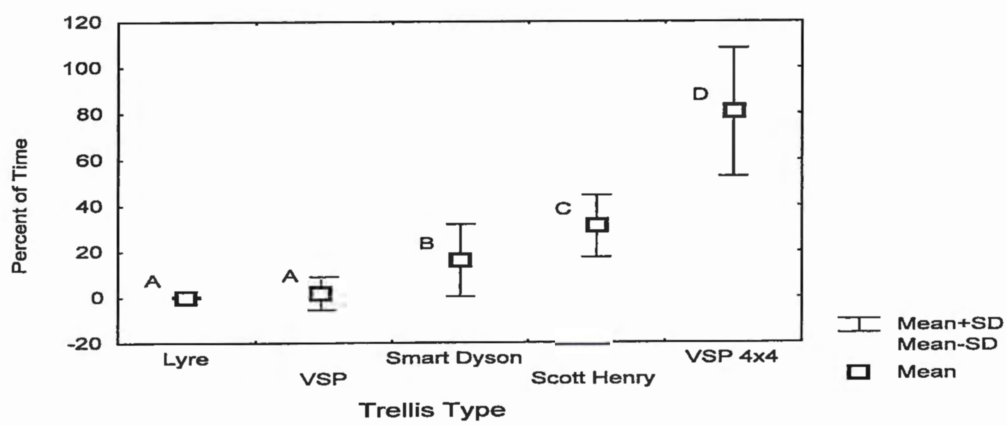


Figure 37. Average percent of time spent in sagittal plane ($30° \leq \theta$).

Velocity Analysis

Descriptive statistics for trunk velocities in the three principal planes of motion are shown in Table 13.

Table 13. Descriptive statistics: Trunk velocity.

	Trellis	Mean (deg/sec)	SD
Coronal	Lyre	4.03	0.96
	VSP	5.02	1.17
	Smart Dyson	4.86	1.27
	Scott Henry	5.34	1.84
	VSP 4x4	4.37	1.83
Sagittal	Lyre	3.67	1.17
	VSP	3.10	1.17
	Smart Dyson	5.01	1.63
	Scott Henry	6.63	2.23
	VSP 4x4	5.56	2.57
Transverse	Lyre	3.99	1.52
	VSP	3.01	1.27
	Smart Dyson	2.81	0.94
	Scott Henry	3.05	0.98
	VSP 4x4	1.85	1.04

Table 14 shows the ANOVA results for the velocity data of the trunk. Significant differences among the trellis systems were noticed for all three planes of motion.

Table 14. ANOVA results for trunk velocities.

	DF Effect	MS Effect	DF Error	MS Error	F	p-level
Lateral	4	3.009	40	0.959	3.138	0.025*
Sagittal	4	22.371	40	2.199	10.171	0.00*
Transverse	4	6.406	40	0.425	15.080	0.00*

* Significant at $p < 0.05$

Figure 38 through Figure 40 show the average trunk velocities in the coronal, sagittal and transverse planes, respectively. Newman-Keuls comparisons were completed at the $p<0.05$ level for all conditions. Dissimilar letters as shown on each figure indicate significant differences between the trellis systems.

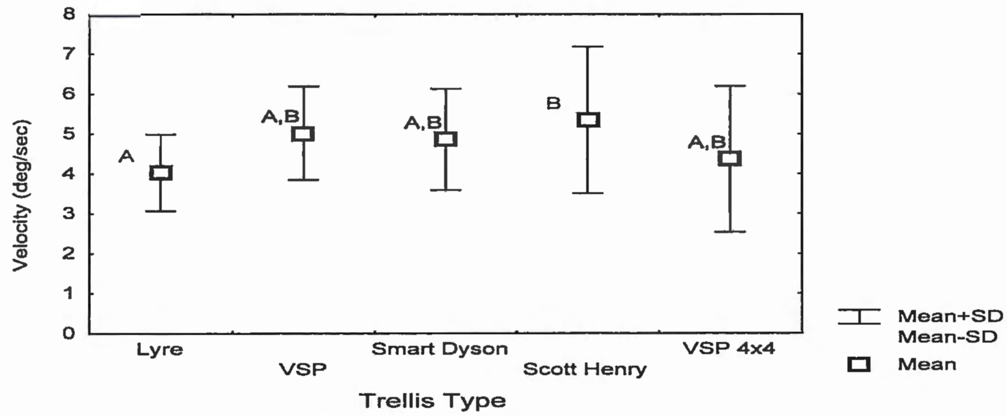


Figure 38. Average trunk velocity in coronal plane.

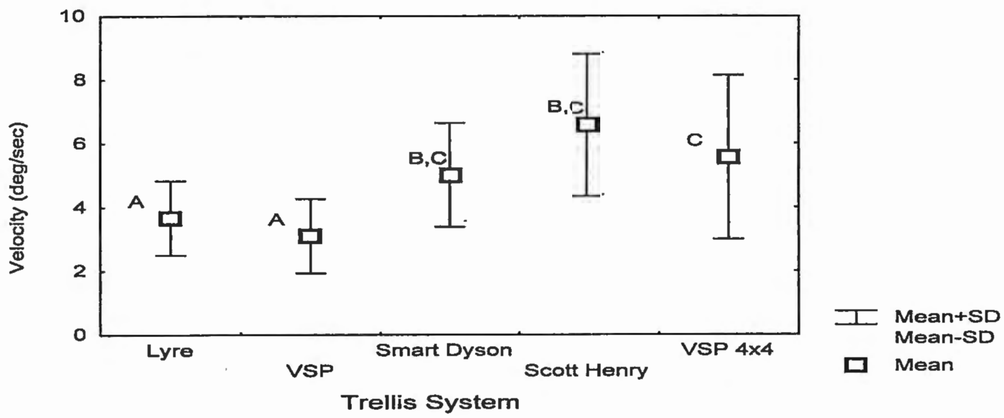


Figure 39. Average trunk velocity in sagittal plane.

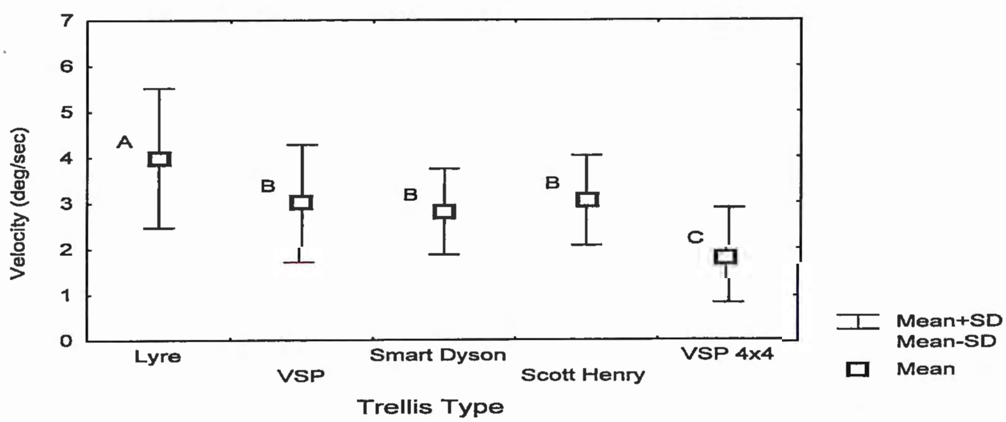


Figure 40. Average trunk velocity in transverse plane.

Correlation Analysis

Correlation coefficients were determined for comparisons made between the wrist and sagittal trunk postural data and between the wrist/trunk postural data and pruning height. The relationships were determined to be practically significant for those comparisons with $r^2 > 0.5$.

Comparison Between Wrist and Trunk Postures

Sagittal flexion of the trunk was experienced among all participants and resulted in the largest range of motion compared with the coronal and transverse planes. Therefore, an analysis was completed to determine if a relationship exists between the average posture specific wrist conditions and average sagittal flexion of the trunk. Figure 41 through Figure 44 show significant correlations for the left extension, left flexion, left radial and right flexion wrist conditions with sagittal flexion of the trunk, respectively.

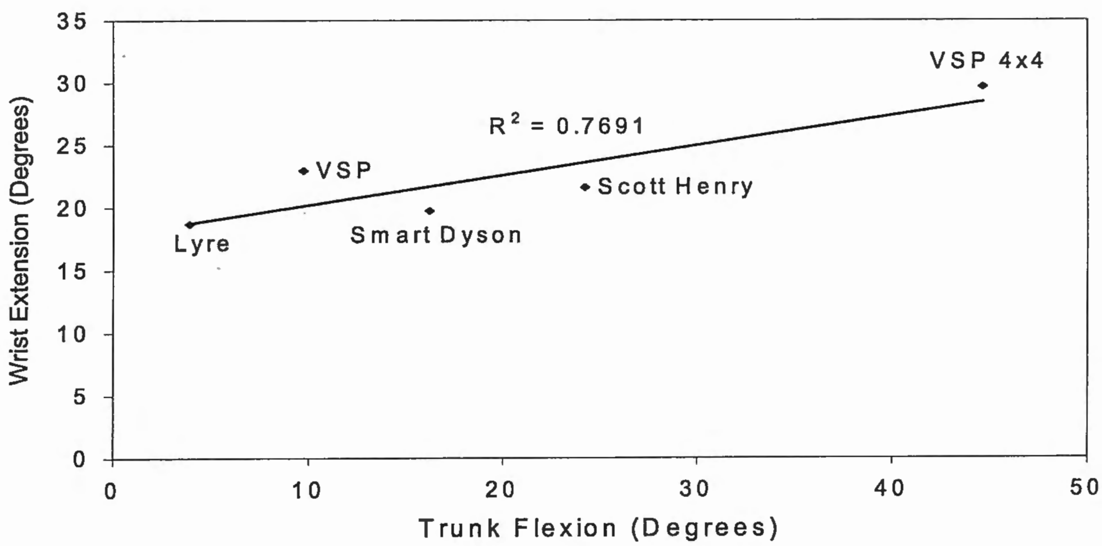


Figure 41. Left wrist extension vs. sagittal trunk flexion.

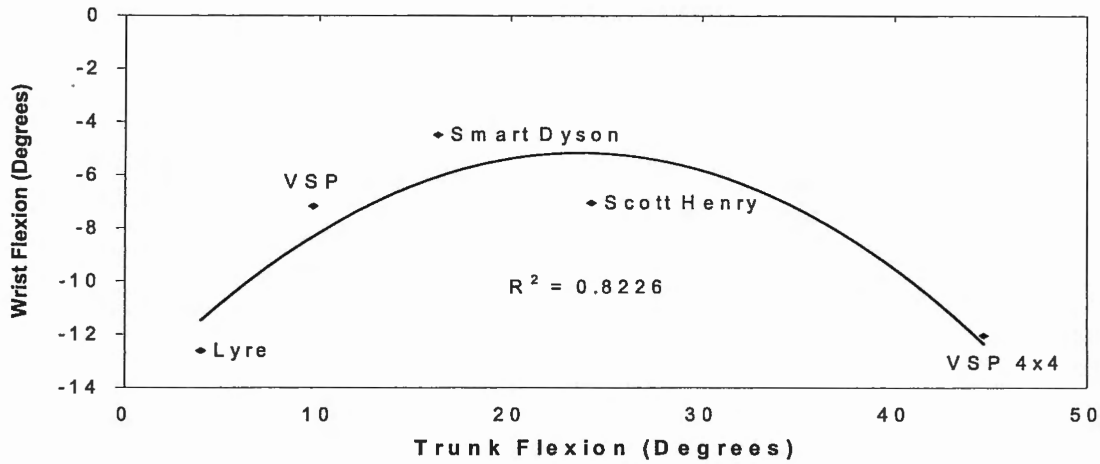


Figure 42. Left wrist flexion vs. sagittal trunk flexion.

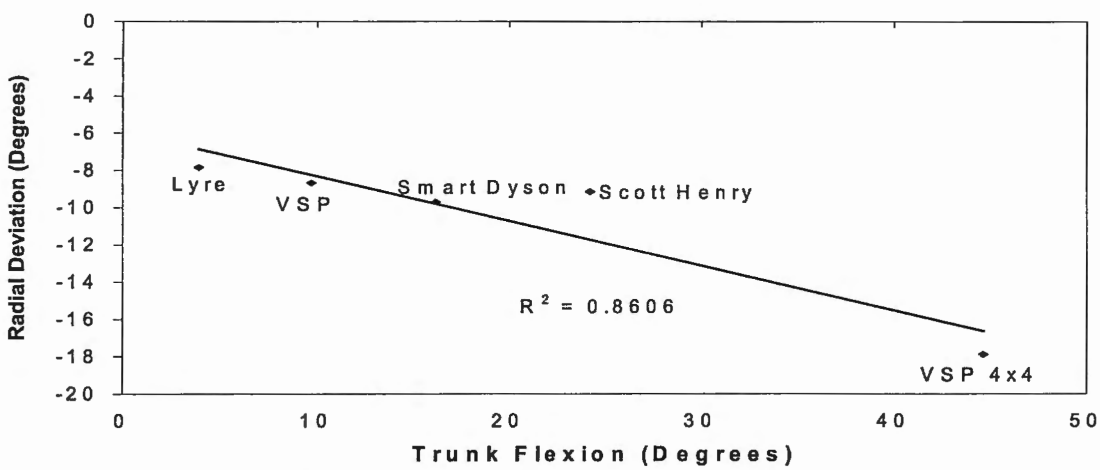


Figure 43. Left radial deviation vs. sagittal trunk flexion.

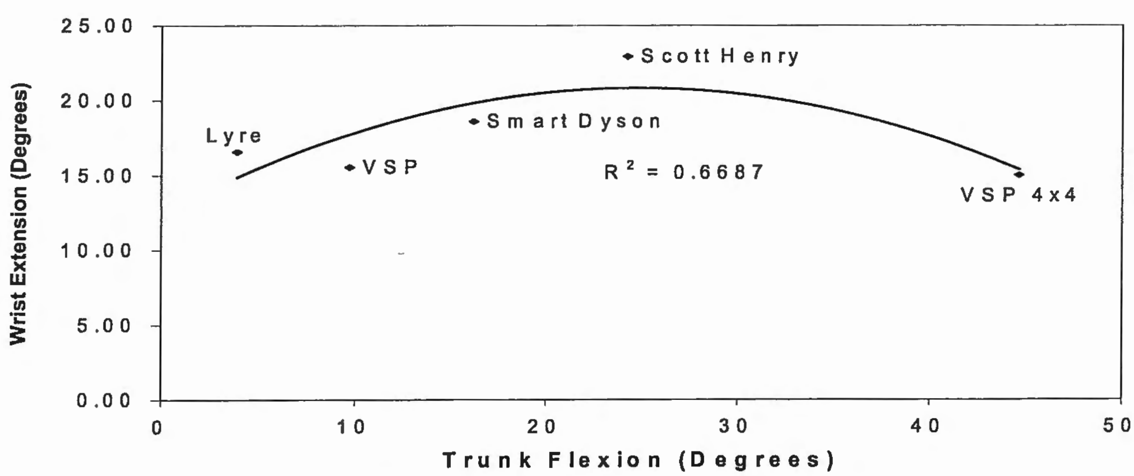


Figure 44. Right wrist Extension vs. sagittal trunk flexion.

Comparison Between Wrist/Trunk and Pruning Height

Correlation coefficients were determined for comparisons between average trunk/wrist postures and pruning height. Figure 45 and Figure 46 show the significant relationships for the left flexion and left radial conditions, respectively. Figure 47 through Figure 49 show the significant relationships for the sagittal flexion, sagittal extension and coronal right conditions, respectively.

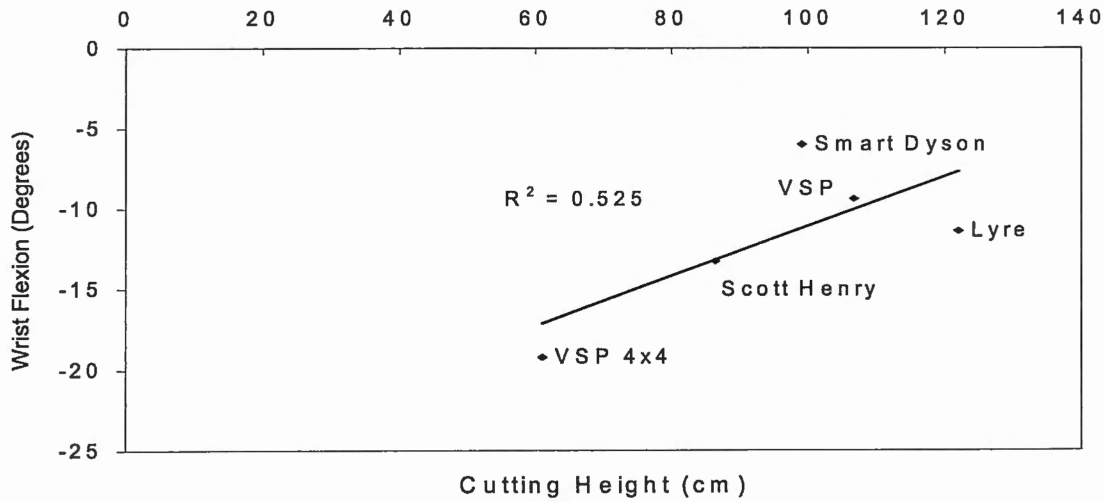


Figure 45. Average left wrist flexion vs. pruning height.

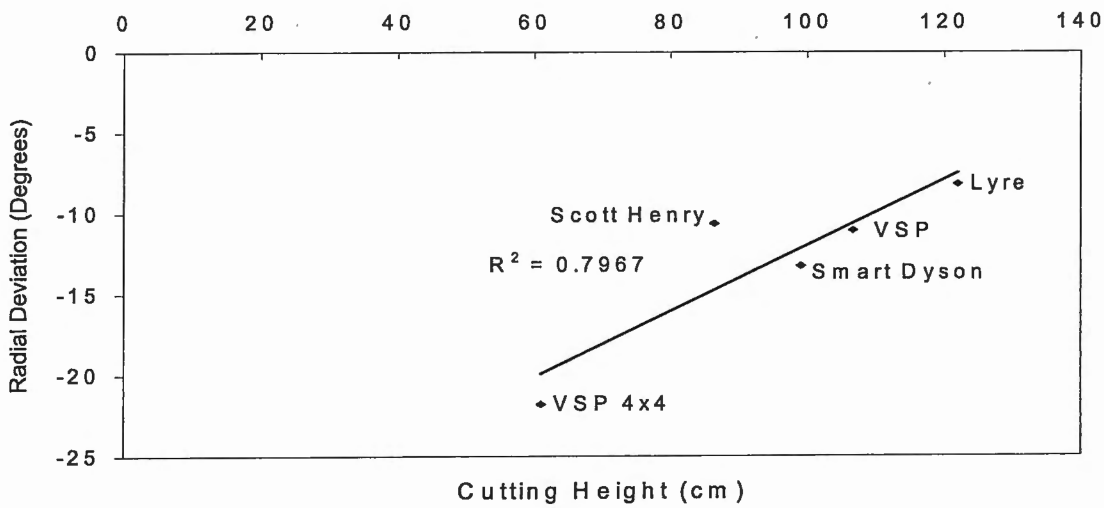


Figure 46. Average left radial deviation vs. pruning height.

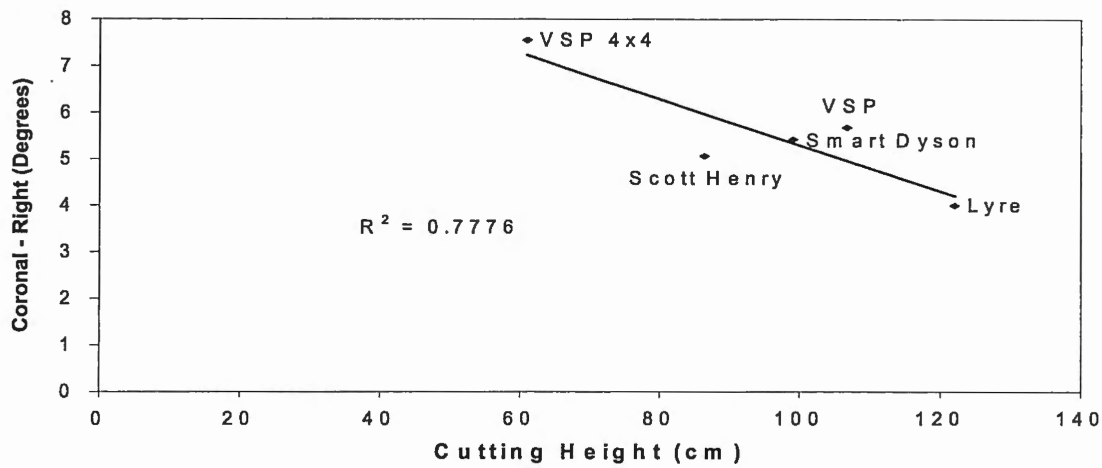


Figure 47. Average coronal posture vs. pruning height.

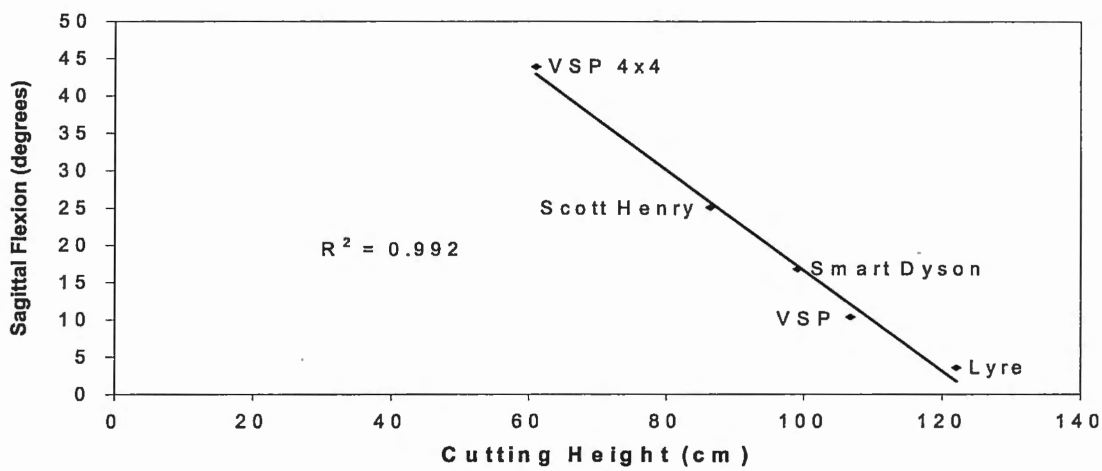


Figure 48. Average sagittal flexion vs. pruning height.

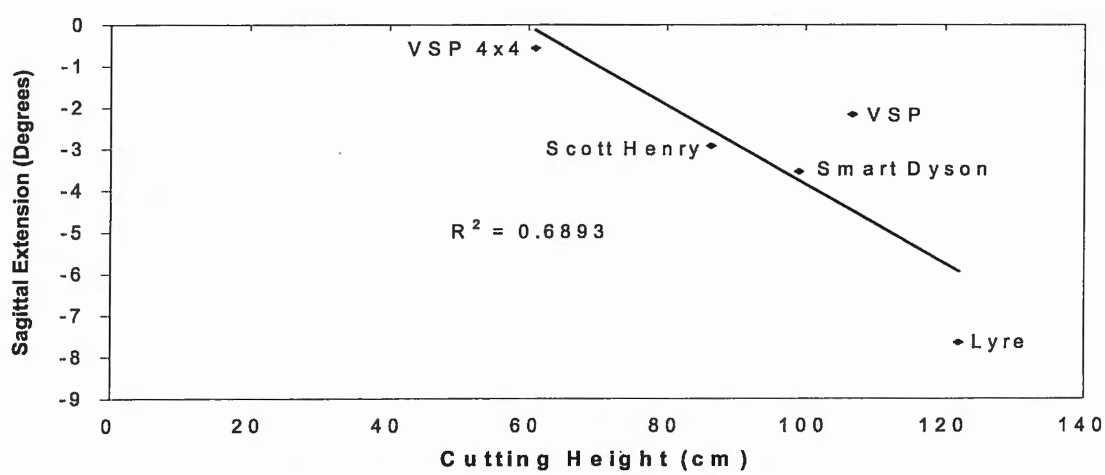


Figure 49. Average sagittal extension vs. pruning height.

Subjective Ranking of Trellis Systems

Each participant participated in a subjective ranking of the trellis systems upon completion of the data collection session. The trellis systems were ranked from 1 (easiest) to 5 (hardest) as shown in Table 15. The results of the nonparametric test are shown in Table 16. A graphical representation of the subjecting ranking is shown in Figure 46.

Table 15. Subjective ranking of trellis systems

Subject	Lyre	VSP	Smart Dyson	Scott Henry	VSP 4x4
1	5	1	2	3	4
2	4	1	2	3	5
3	4	1	3	5	2
4	2	1	4	3	5
5	4	1	2	3	5
6	3	2	5	4	1
7	5	1	3	2	4
8	2	1	3	4	5
9	4	1	2	3	5

Table 16. Friedman ANOVA and Kendall Concordance Coefficient

Trellis	Average Rank	Sum of Ranks	Mean	Std.Dev.
Lyre	3.67	33.00	3.67	1.12
VSP	1.11	10.00	1.11	0.33
Smart Dyson	2.89	26.00	2.89	1.05
Scott Henry	3.33	30.00	3.33	0.87
VSP 4x4	4.00	36.00	4.00	1.50

Friedman ANOVA and Kendall Coeff. of Concordance
ANOVA Chi Sqr. (N = 9, df = 4) = 18.48889 p < .00099
Coeff. of Concordance = .51358 Aver. rank r = .45278

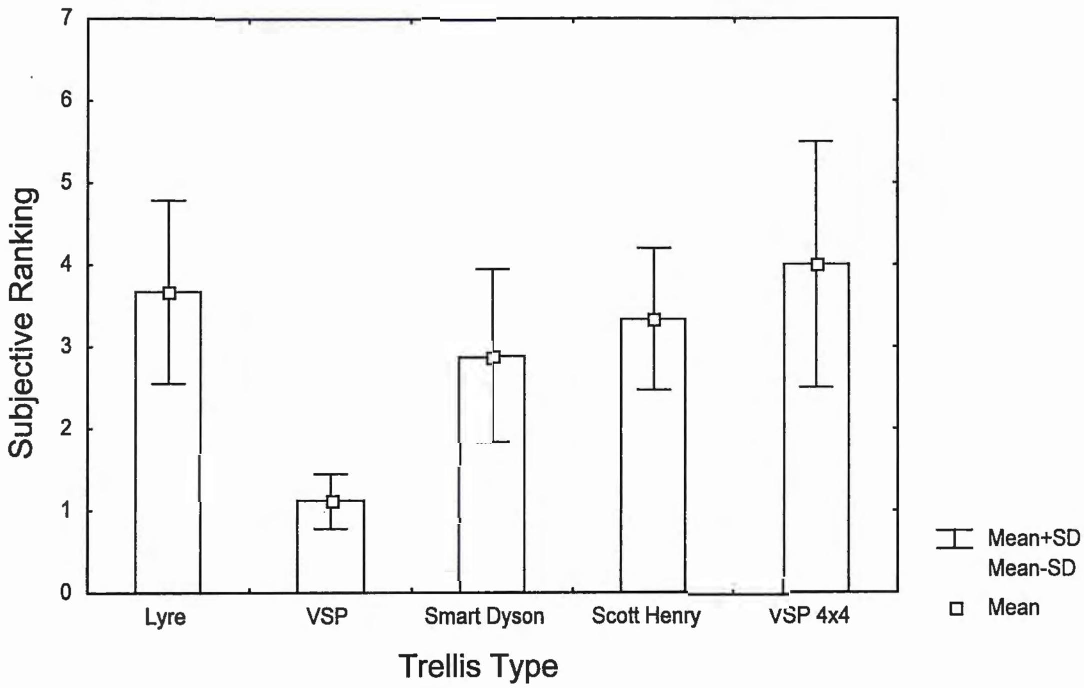


Figure 46. Subjective ranking of trellis systems, 0 = easiest, 5 = hardest.

DISCUSSION

Prior studies have shown that frequent and constant work actions may result in injuries sustained to the soft tissues of the human body. Predominant risk factors responsible for overuse injuries have been identified in work tasks that include repetitive motions, overexertion, and extreme postures. The pruning of winegrape vines encompasses these risk factors and may have detrimental effects on the health of the worker.

The purpose of this study was to quantitatively determine if differences in the relative risk of developing MSDs among different trellis systems exist. The results of this study showed significant differences among the trellis systems for several parameters concerning the wrist and the trunk. Significant correlations were found for comparisons between the postures of the wrist and trunk. In addition, significant correlations were found for comparisons between the wrist/trunk postures and pruning height. Therefore, the implications of these results identify the importance of selecting a trellis system that would have minimal harmful effects on the health of the worker.

Wrist Factors

The postural wrist analysis revealed significant differences among the trellis systems. For the overall wrist postures, every measure resulted in significance with the exception of the radial/ulnar deviation for the right hand.

Overall, the trellis types resulted in extension of the left wrist. The average posture of the left wrist in the flexion/extension plane for the VSP 4x4 system was 24.5°. The magnitude of wrist extension for the VSP 4x4 was significantly different compared with the other systems. The larger extension values may be due to the forced posture of the wrist to accommodate the relatively low cutting height. The VSP 4x4 tends to position the participant into squat/stoop postures. These extreme postures seem to affect the left (non-cutting) hand, which is used to support and remove the branches that will be and have been cut.

The averaged overall postural data for the radial/ulnar plane resulted in significant ulnar deviation of the left wrist for all trellis systems. The ulnar deviation may be explained by the "naturally assumed" posture of the wrist while grasping and positioning branches with the left hand. A significant difference was noticed between the VSP 4x4 with the Lyre and Scott Henry systems for the overall radial/ulnar deviation of the left wrist. The VSP 4x4 resulted in the least amount of ulnar deviation with an average of 1.92° compared with the other systems. This low average may be the result of the squat/stoop postures assumed by each participant and the decreased branch density assigned to this system. The squat/stoop posture positions the participant closer to the branches, which may minimize the deviation of the wrist in the radial/ulnar plane. The vines placed onto the VSP 4x4 is a relatively small vine resulting in lower number of branches. The branch densities among all trellis systems, with the exception of the Lyre and the VSP 4x4, were identical and may explain the corresponding magnitudes of ulnar deviations. The branch density of the Lyre was identical to the VSP 4x4 yet experienced an average of 11.5° of ulnar deviation. The increased height of the Lyre system in combination with the multidirectional growth may orient the wrists in larger ulnar deviations. The overall characterization of the ulnar and radial postures may be best explained by the random position of the branches. The branch placement will have a direct effect on the radial/ulnar wrist postures as the participants constantly adjust their wrist position to accommodate the multidirectional growth of the shoots.

The averaged overall postural data for the flexion/extension plane revealed extension of the right wrist for all trellis systems. The extension of the right (cutting) hand was significantly increased for the Scott Henry system with an average of 10.2° compared with the other trellis systems. This is further emphasized by the posture specific results indicating approximately 17.4° of extension for the Scott Henry. This may be explained by the design configuration of the system, which tends to compel the worker to orient the wrist in increased extension. The majority of participants assumed a stooped posture while pruning the Scott Henry system. In addition, the palm of the cutting hand was primarily directed toward the ground. It is assumed that wrist extension increases as cutting height decreases, while maintaining a stooped posture, and wrist flexion increases as cutting height increases, while maintaining an upright posture. Adjustments are made by the wrist to accommodate the change in cutting height to maintain the downward orientation of the palm. The downward orientation of the palm may be due to the perpendicular placement of the pruning shear with the target branch. Therefore, the specific cutting height of the Scott Henry may be responsible for the increase in wrist extension. Although the VSP 4x4 results in the lowest cutting height, the participants are positioned in a squat posture essentially increasing the cutting height relative to the midsection of each participant.

The posture specific analysis revealed significant differences for the extension and ulnar conditions for the left wrist. The average extension of the left wrist for the VSP 4x4 was 29.7° and was highest among the other systems. This result was similar to what was determined for the overall posture condition. However, the posture specific ulnar deviation was lowest for the VSP in comparison to the VSP 4x4 in the overall posture condition. The overall condition revealed least amount of ulnar deviation for the VSP 4x4. However, averages obtained from the overall condition depend on the radial and ulnar deviation postures. The positive values associated with ulnar deviation may be offset by the larger negative radial deviation values. Therefore, the posture specific ulnar deviation condition results in an improved postural representation.

The individual ANOVAs evaluation compared the average percent of time within a specific range (i.e., range 1) among all trellis systems. Significance was noticed for the flexion/extension of the left hand for ranges 2 and 4 only. The VSP 4x4 resulted in the lowest percent of time spent in the neutral range (range 2) with an average of 13.7%. The VSP resulted in the highest percent of time with an average of 51.2% in this range. The large percentage observed for the VSP suggests that the left hand is within a neutral range for at least 50% of the time.

The VSP 4x4 (left wrist) resulted in the highest percent of time in extreme extension (range 4) with an average of 42.1% compared with the other systems. The second prevalent range for the VSP 4x4 was range 3 with an average of 35.1%. Therefore, 75% of total pruning time is spent in extension postures exceeding 15° for the VSP 4x4. This coincides with the results obtained from the significantly larger extension values observed for the posture specific wrist condition.

There were no significant differences noticed among the trellis systems for the remaining wrist postures. The VSP resulted in the highest percent of time spent in neutral postures (range 2) with an average of 66.3% for the left radial/ulnar deviation condition. The VSP also experienced the lowest percent of time in extreme ulnar deviation (range 4) with an average of 14.5% compared with the other systems. The right wrist experienced neutral postures (range 2) for the majority of the time for the flexion/extension and radial/ulnar planes. The neutral positioning of the right wrist (cutting hand) may be an efficient posture that allows participants to maximize the cutting force applied to the pruning shear. In addition, stability is maintained in the wrist thus minimizing extraneous muscular contractions of the forearm, which may limit the effects of fatigue.

There was no significant difference noticed for the wrist velocities among all postures. The average velocity did not exceed 10 deg/sec across all conditions. The velocities were consistent within each posture specific condition. This may indicate that movements experienced by the wrists were for postural adjustments rather than for moving the wrist at higher velocities for task specific circumstances. An analysis was not completed on the acceleration of the wrist due to the low collection frequency of 20 Hz.

Wrist Implication

Flexion and extension angles of the wrist in excess of 45° has been suggested as unsuitable in the occupational setting and may increase the risk of developing MSDs of the wrist (Armstrong, 1986; Punnett and Keyserling, 1987; Stetson, 1991). The results of this study have determined that average flexion and extension angles have not exceeded 30°. It has also been suggested that MSD risk increases when wrist postures in the radial/ulnar plane exceed 50% of maximal radial/ulnar postures (Stetson, 1991). Maximal radial and ulnar deviations were not reported. However, based on the average postural and percent of time data, the majority of the left and right wrist postures were predominated by neutral postures (range 2).

Marras and Schoenmarklin (Marras and Schoenmarklin, 1993) demonstrated the significance of kinematic parameters such as velocity and acceleration for quantifying the relationship between occupational risk factors and development of CTDs of the wrist. The results from their study determined that low risk group mean velocities for the flexion/extension and radial/ulnar postures were 28.7 deg/sec and 17 deg/sec, respectively. Mean velocities across all posture specific conditions did not exceed 10 deg/sec.

As previously mentioned, cutting height may dictate the deviation of the wrists from the neutral position in the flexion/extension plane. The combination of cutting height with the random growth direction of the branches further increases the displacement of the wrists from the neutral position. With the random growth patterns of the branches being equal among all trellises, cutting height may have a heavy influence on the deviation of the right wrist. The cutting height of the VSP allows the worker to maintain the forearms at an approximate ninety-degree angle with the arms. This forearm-arm configuration may position the wrist in predominantly neutral postures while maintaining the perpendicular alignment of the pruning shear with the target branch. The position of the left wrist depends on the direction of growth of the branches. As previously mentioned, the left wrist is used for the removal of the branches that have been cut.

Based on the postural and velocity parameters of this study, the overall risk of developing CTDs seems to be minimal. The postural and velocity magnitudes are well below the standards that have been established. However, the combination of high force application and high repetition with kinematic parameters should not be overlooked. If a recommendation on a trellis system were to be made based on the wrist factors (posture, velocity, % of time), the VSP would be suggested. Overall, the VSP resulted in the highest percentage of time spent in neutral postures (range 2) among the other trellis systems for the flexion/extension and radial/ulnar planes.

Trunk Factors

The differences observed for the overall trunk position in the coronal plane were statistically significant. However, the average range of motion within the coronal plane across all trellis systems was 8° (-5° left and 3° right). Significant differences were also noticed for the coronal right and left conditions. Although significance was achieved, the average range of motion within the coronal right and left conditions across all trellis systems was approximately 4° and 5°, respectively. Therefore, these differences may be due in part to positioning of the trunk based on individual preference. Similarly, significance was achieved for the transverse right condition. However, this difference can also be attributed to variation in individual preference. The resulting average range of motion was approximately 2°.

Due to the assumption that the differences observed for the coronal and transverse conditions were the result of individual postural adjustments, attention will be primarily focused on the sagittal and extension trunk conditions.

Significant differences among trellis systems were observed for the overall sagittal posture condition. As expected, there was a direct relationship between trellis height and trunk flexion angles. The Lyre (highest pruning level) was the only system that resulted in slight extension of the trunk with an average of approximately 4°. However, the Lyre required participants to cut in a constantly elevated shoulder posture. The VSP system resulted in the lowest trunk flexion angles with an average of 9.4° compared with the other systems. This indicates that this system may provide an optimal cutting height to decrease risk of low back disorders. As expected, the VSP 4x4 system showed the highest levels of trunk flexion due its low cutting height. The average sagittal trunk flexion for the VSP 4x4 was approximately 45°.

As previously mentioned, extension of the trunk was the average trunk posture assumed while pruning the Lyre system. The Lyre system resulted in the largest percent of time spent in sagittal extension compared with the other systems. The average percent of time spent in extension (range 1) was 67.3% compared with 17.1% for the Scott Henry, which had the second highest percentage. The extension of the trunk could be harmful to the posterior elements of the lumbar spine (Adams et al., 2000). In addition, much of the cutting was performed with the arms above the shoulder. The body posture assumed was similar to that of reaching for an object above the shoulders causing extension of the trunk. An analysis of the shoulder was not conducted for this study. However, a review of the collected video showed the raising of the arms above the shoulders for the majority of the pruning task across all participants. (Frost and Andersen, 1999) defined occupational tasks that position the hands above the acromion as harmful to the shoulder. The elevated hand position causes impingement of the subacromial structures. The repetitive impingement may lead to MSDs of the structures that comprise the shoulder. In addition, raising the arm above the shoulders has been shown to increase the intramuscular pressure within the supraspinatus leading to ischemic conditions. Therefore, the Lyre trellis would not be an ideal choice.

The VSP resulted in the largest percent of time spent in the neutral range (range 2) with an average of 73.2%. In contrast, the VSP 4x4 resulted with an average of 4.5%. The Lyre, it was interesting to observe the downward trend in percent of time spent in range 2 as cutting height decreased. This clearly showed the direct relationship between trunk flexion and cutting height. As cutting height decreased, the amount of time spent in neutral postures decreased as flexion of the trunk was increased to accommodate the lower cutting height.

The percent of time spent in trunk flexion angles that exceeded 30° were significantly higher for the VSP 4x4 compared with the other systems. The VSP 4x4 averaged 81% compared with the second highest percentage of 31% for the Scott Henry. An increase in trend was noticed as cutting height increased. As cutting height decreased, the amount of time spent in excessive flexion angles increased. This result supports the dependency of trunk flexion on pruning height.

Significant differences were noticed among the trellis systems for the sagittal trunk velocities. However, the range of velocities among the trellises was minimal ranging from 3 -7 deg/sec. The lowest average velocity was observed for the VSP with an average of 3.1 deg/sec. In contrast, the Scott Henry averaged 6.6 deg/sec. The Lyre and VSP have similar average velocities and are significantly lower compared with the other systems. The Scott Henry, Smart Dyson and VSP 4x4 trellises resulted in similar velocities. These trellises required participants to position themselves in stoop/squat positions due to the low pruning heights. Therefore, the constant flexion and extension of the trunk while maneuvering from one branch to another may explain this result.

Trunk Implications

Benchmarks concerning the exposure of the lower back to occupational risk factors have not been well defined. Numerous studies have resulted in qualitative characterizations of risk factors that contribute to the development of lower back disorders (LBD). Marras and colleagues (Marras et al., 1995) have identified risk factors such as work intensity, static work postures, frequent bending and twisting, and repetition as occupational risk factors associated with LBD. The risk of developing LBD increased as a combination of these factors was present.

The trunk flexion angles resulting from the VSP 4x4 were significantly higher than the other trellis systems. In addition, the percent of time spent in extreme flexion was the highest for the VSP 4x4 compared with the other systems. Punnett and colleagues (Punnett et al., 1991) have determined that the development of LBD increased as trunk flexion and exposure time in extreme flexion angles was increased. The VSP resulted in the least amount of trunk flexion. In addition, approximately 75% of the time was spent in neutral trunk postures in the sagittal plane. Based on this conclusion, the risk of developing LBD is minimal with the VSP in comparison with the other trellis systems.

Marras and colleagues (Marras et al., 1999) determined that trunk velocity was a good indicator for the risk of developing LBD. From this study, a high and low risk group membership for average sagittal velocity was determined to be 11.74 deg/sec and 6.55 deg/sec, respectively. Among all trellis systems, the Scott Henry resulted in the highest average sagittal velocity. This average was 6.63 deg/sec and is fairly close to the low risk group membership. The sagittal velocities determined for the other trellis systems are significantly lower than the Scott Henry. Therefore, concerns regarding the effects of velocity on the development of LBD are minimized.

Correlation Between Variables

Notable correlations between the wrist and sagittal trunk postural data were observed. The comparisons that were significantly correlated warrant further investigation to better understand the behavior of specific relationships. However, of particular interest was the relationship between the flexion of the left wrist and sagittal trunk flexion. The Lyre and VSP 4x4, both of which encompass relatively extreme trunk postures, result in the largest wrist flexion angles compared with the other trellises. Therefore, the implication from this result emphasizes the interaction effect of risk factors. The relatively large trunk flexion and extension angles in combination with increased wrist flexion increase the risk of developing MSDs of both the wrist and the back.

The comparison between sagittal flexion and cutting height resulted in linear relationship with $r^2 = 0.992$. This finding further supports the association between trellis height and trunk flexion angles as previously discussed.

General Discussion

The increased trunk flexion and increased wrist flexion angles make the VSP 4x4 system the least desirable from a MSD risk standpoint. The subjective ranking of the trellis systems further validates this claim. The elicited responses were unfavorable for the VSP 4x4 system. A major complaint was the relatively low height of the system. The Lyre system would also be undesirable due to the combination of increased trunk extension, increased wrist flexion and increased arm flexion angles. The majority of the participants complained about the effects of fatigue due to the excessive arm flexion required for reaching the higher branch height. The average trunk flexion values for the Smart Dyson and Scott Henry systems were significantly higher than the VSP. It must be noted that the overall body posture for pruning these systems consisted of squat/stoop postures.

The results obtained from the trunk and wrist analysis for the VSP system unanimously reduces the relative risk of developing MSDs compared with the other trellis systems. In addition, the subjective rankings of the trellis systems are overwhelmingly in favor of the VSP. The significance of this finding may have important implications to vineyards that are currently considering to plant or re-plant new vines. Since there are no substantial differences with respect to grape quality or vine productivity among the variety of trellis systems, the finding of this study will be disseminated to advocate the use of the VSP.

Limitations

The study has several limitations. Firstly, the study focused on five simulated trellis systems that reflected the average design characteristics of each corresponding system. In other words, since there is variability within a given system, it is conceivable, for example, that a lower height Lyre system to be better than a high VSP system. However, the information presented should provide general guidelines for a preferred cutting height. Secondly, the study did not evaluate the forces applied during pruning. Elevated and repetitive cutting force, combined with even moderate wrist postures could lead to increased risk of CTDs of the wrist (Silverstein et al., 1986). The assumption was that, since the participants were cutting similar material in each system, the forces are expected to be rather similar. We are currently exploring the validity of this assumption and its implication to pruning and other cutting tasks. Furthermore, the workers were provided with identical pruning shears; however, this was necessary to avoid the potential confounding effect of shears design.

Future Studies

A detailed biomechanical analysis of the pruning task can be completed. Specifically, focus can be placed on identified risk factors responsible for the development of MSDs. For example: 1) the force exerted onto pruning shears, 2) the interaction of kinetic and kinematic parameters of the wrist, 3) cycle time analyses used to determine the repetitiveness and duration of the pruning task pertaining to the wrist and trunk, 4) lower extremity and shoulder postural assessments related to each trellis system and 5) correlation of quantitative/direct measurement postural data with those obtained by subjective observational methods. Most of these issues are currently being looked at by our research group.

CONCLUSION

This study was able to demonstrate the relative risk of developing MSDs among five of the common trellis systems used in the winegrape industry. The study have shown that The Lyre and VSP 4x4, both of which encompass relatively extreme trunk postures, result in the largest wrist flexion angles compared with the other trellises. Therefore, the implication from this result emphasizes the interaction effect of risk factors. The relatively large trunk flexion and extension angles in combination with increased wrist flexion/extension observed in these systems increase the risk of developing MSD's of both the wrist and the back. On the other hand, it was observed that the VSP system, overall, resulted in both the most time spent in neutral trunk posture combined with acceptable writ postures. The significance of these findings may have important implications to vineyards that are currently considering to plant or re-plant new vines. Since, for a given grape variety, the trellis height does not substantially affect grape quality or vine productivity (Wolpert, 2002), the findings of this study will be disseminated to advocate the use of the VSP system (around 106 cm), and avoid the VSP 4x4 (around 61 cm) and the higher (above 106 cm) Lyre systems.

STUDY 3-ERGONOMIC EVALUATION: HARVEST SIMULATION

OBJECTIVE

The objective of this study is similar to the pruning study described above, which is to quantitatively evaluate the harvesting task of five commonly used trellis systems throughout the winegrape vineyard industry. This ergonomic evaluation will be based on the relative risks of developing MSDs to the wrist and the lower back while harvesting using a controlled simulation approach. Again, we anticipate that the results of this study will assist vineyard proprietors to select an optimal trellis system concerning minimizing MSD risk exposure to the employee. Since the approach of this study was similar to the pruning study, the level of details provided in this study will be minimal.

METHODOLOGY

Participants

Twelve male healthy volunteers, with an average of 7.5 years of harvest experience, participated in this study. The volunteers were compensated workers at the UC Davis vineyards, which is administered by the campus Viticulture and Enology department. The mean age was 42 years (9.0 std. dev.), and mean stature was 169.1 cm (5.9 std. dev.) (see . All participants were screened with regard to any current or recent MSD of the back, and upper extremities.

Apparatus

Five simulation trellis systems were constructed for this study: VSP 4x4, Smart Dyson, Scott Henry, VSP, and Lyre. The cutting heights were based on average vineyard standards and are as follows: 61.0 cm-VSP 4x4, 86.4 cm-Smart Dyson, 99.1 cm-Scott Henry, 106.7 cm-VSP, and 122 cm-Lyre. The row length for all trellis systems was approximately 9.1 m. One-lb rice bags were used to simulate typical grape clusters. The systems used are shown in .

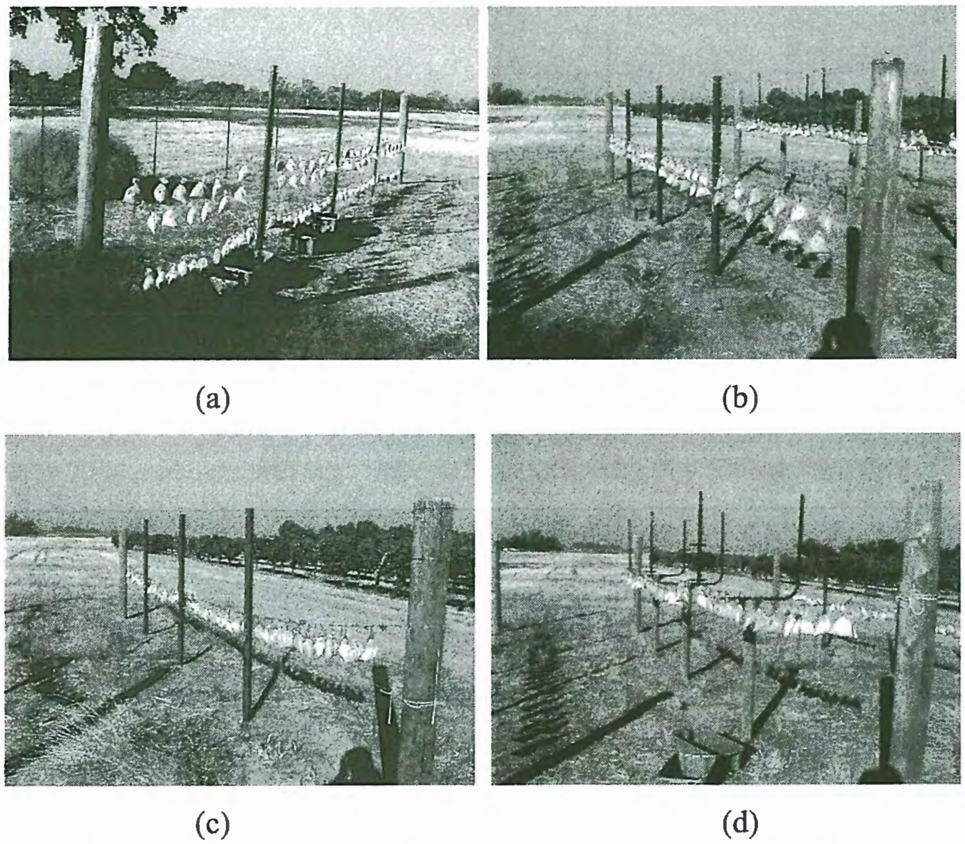


Figure 50. Harvest simulation trellises: a) Scott-Henry (middle two rows) and VSP 4x4 (bottom row), b) Smart Dyson, and d) Lyre.

The Biometrics wrist electrogoniometer (Biometrics Ltd, UK), was used to capture the workers wrist joint motion. The device is secured on the participant's hand and forearm with surgical tape, and the data are stored on a portable data logger.

Again, the Lumbar Motion Monitor (LMM) (Chattecx Corp., Hixon, TN) was used to track the motion of the trunk in the three principal anatomical planes (sagittal, transverse and coronal). Figure 51 shows a participant equipped with the LMM and Biometrics wrist electrogoniometer while performing a harvest trial.

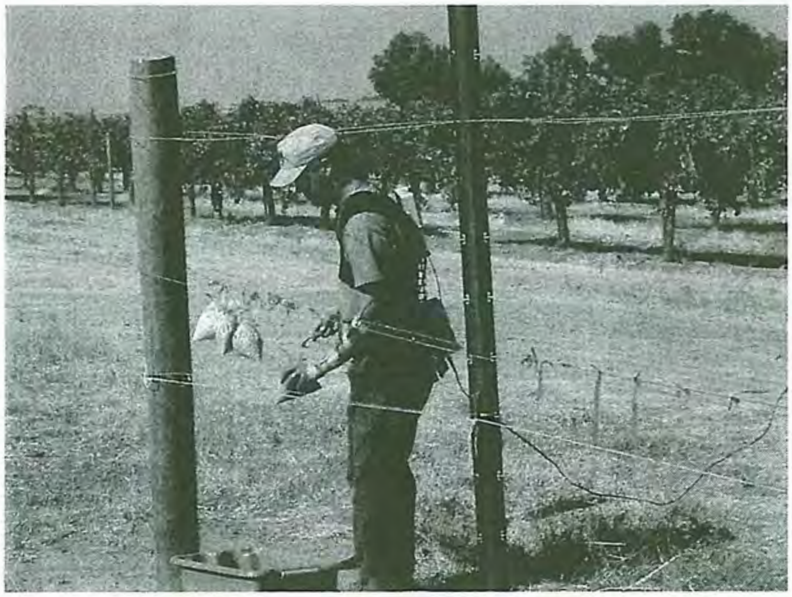


Figure 51. A participant harvest a simulated trellis system.

Experimental Design

The study was a one-way within-subject design with five levels (trellis systems, discussed above). The dependent variables were classified into two categories: 1) right and left mean wrist postures and mean velocities (flexion/extension, and radial/ulnar deviation), and 2) mean trunk postures and mean velocities (coronal, transverse, and sagittal angles). The pruning sequence for the trellis systems was randomly presented across all participants.

Experimental Procedure

The procedure is similar to the one described in the pruning study above, hence only major issues will be discussed here. Each participant agreed to participate in the study and signed an informed consent form.

With the participant properly fitted, data collection followed. Data were collected on two participants per day. Each participant was instructed to harvest half of each row per trellis system and to perform the harvesting task as they would normally. The row length was determined to be sufficient due to the repetitive nature of the task. Once the participant finsihed the assigned row, they moved to the next system until they finish cutting the rice bags of all systems. Participants were asked to only drop the clusters (bags) into the available tubs placed on the ground across the row (see Figure 51).

Video recordings for all participants harvesting each system were obtained. In addition, a subjective ranking instrument was verbally administered at the completion of the last trellis system to capture participant's trellis preference. The participants were asked to rank the trellis systems in terms of difficulty pertaining to bodily discomfort from least to most difficult. The participants were told to respond assuming a typical eight-hour work-shift.

Data Analysis

In general, the data analysis was similar to the pruning study. For the wrist postural analyses, descriptive statistics were obtained for each trellis system for the right and left flexion/extension and radial/ulnar deviations. Similarly, for trunk postures, descriptive statistics were obtained for the coronal, sagittal and transverse angles. ANOVAs were also conducted for the postural information.

RESULTS

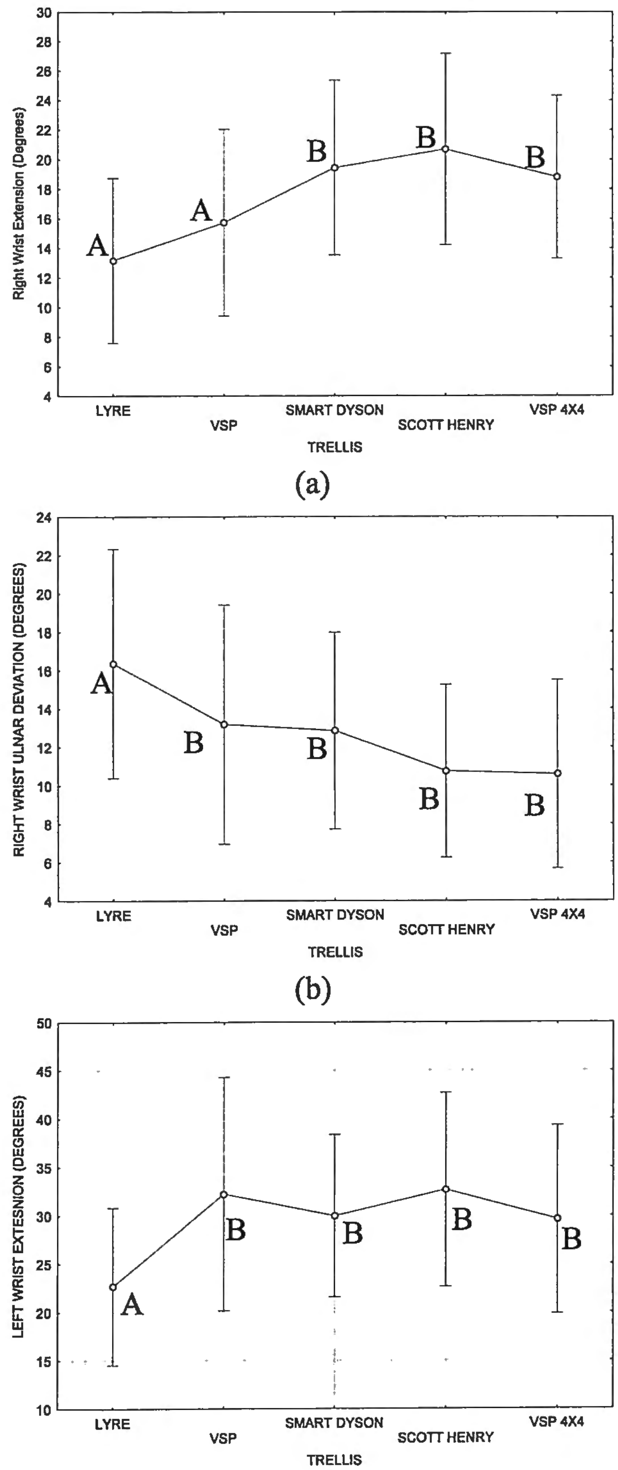
Wrist Postures

Table 17 shows the descriptive statistics for the right and left wrists as well as the ANOVA results. Pos hoc analysis are shown in Figure 52.

Table 17. Wrist posture descriptive statistics for each wrist direction. ANOVA results are indicated below.

		LEFT HAND		RIGHT HAND	
DIRECTION	SYSTEM	Mean (degrees)	Std. dev.	Mean(degrees)	Std. dev.
Flexion	Lyre	-7.1	2.6	-7.7	7.4
	VSP	-7.6	4.3	-6.7	4.0
	Smart Dyson	-8.3	4.2	-7.0	4.4
	Scott Henry	-7.5	4.0	-6.8	6.9
	VSP 4x4	-7.7	4.3	-8.1	7.0
Extension	Lyre	29.2	12.9	13.2	8.3
	VSP	30.8	16.7	15.5	9.0
	Smart Dyson	29.6	10.9	19.4	8.8
	Scott Henry	31.9	13.6	20.7	9.6
	VSP 4x4	29.2	12.9	18.7	7.8
Radial	Lyre	-7.9	3.4	-3.2	1.1
	VSP	-9.4	4.1	-3.1	1.0
	Smart Dyson	-9.2	4.2	-3.9	1.1
	Scott Henry	-9.1	3.0	-6.2	3.6
	VSP 4x4	-8.6	4.1	-5.6	3.1
Ulnar	Lyre	8.1	7.5	15.4	8.0
	VSP	5.8	3.5	12.0	7.7
	Smart Dyson	6.4	4.4	12.2	6.7
	Scott Henry	6.0	4.6	10.7	5.9
	VSP 4x4	5.9	3.1	9.8	6.5

Significant at $p < 0.05$: **Right Ulnar, Right Extension, Left Extension**



(c)

Figure 52. Wrist motion that showed significant differences among trellis systems: a) right wrist extension, b) right ulnar deviation, and c) left extension. Pairs of conditions with dissimilar letters are significantly different from each other (LSD, $p < 0.05$).

Trunk Postures

The trunk posture results for the harvesting task were similar to those observed for the pruning task. Therefore, only a the main results will be presented. Figure 53 and Figure 54 repectively show the average peak sagittal flexion, and the average percent of time spent in trunk flexion ranges while harvesting each of the five trellises.

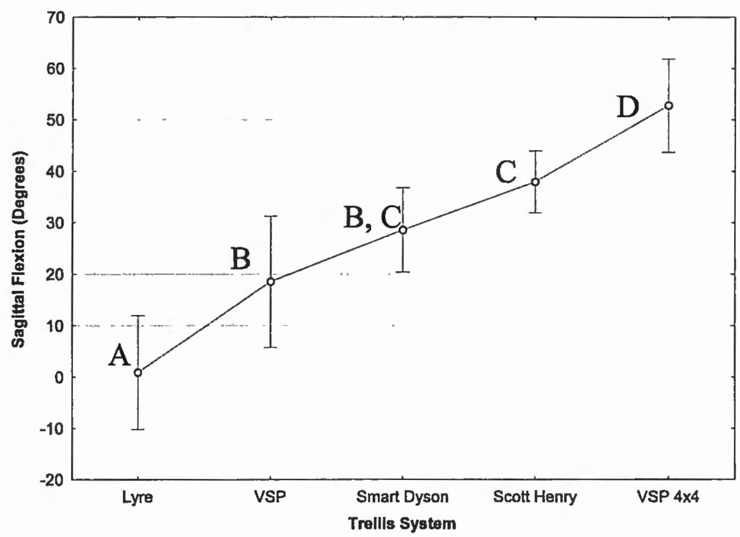


Figure 53. Average peak sagittal flexion for each trellis system. Pairs of conditions with dissimilar letters are significantly different from each other (LSD, $p < 0.05$).

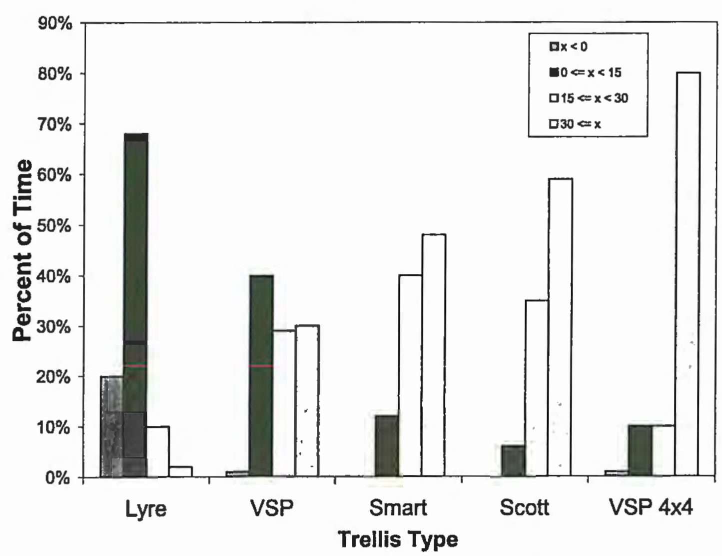


Figure 54. Percent of time spent in each of the trunk flexion categories for each trellis system.

Subjective preference rating of the trellis systems is shown in Figure 55.

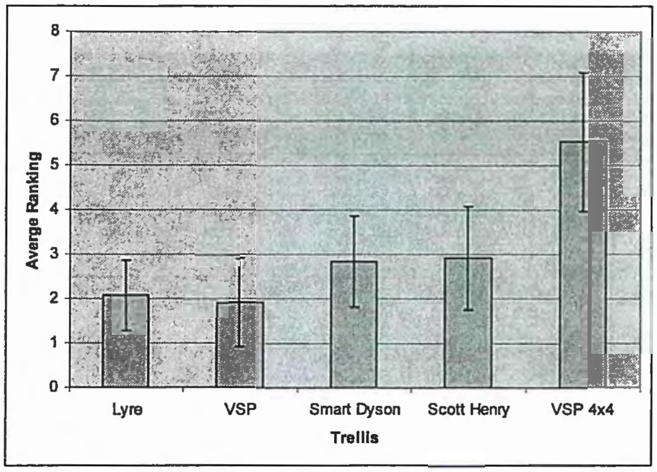


Figure 55. Average subjective rating on ease of use (1= easiest, 7 = hardest) of the trellis systems.

Discussion and Conclusion

The harvesting task exhibited similar results for the **trunk** as in the pruning task. However, during harvesting the wrist motion exhibited different patterns than those observed during pruning. This could be due to tool used in each of the task. In pruning, workers use a pruning shear, whereas in harvest they use a serrated semi-circular knife. It is expected that using the knife is expected to result in more writs motion than using a pruning shear. There seems to be an interaction between the cutting hand (right hand) and the supporting hand (left hand) during harvesting. As the height decreases, the cutting hand undergoes more extension, whereas the supporting hand undergoes less extension. There is an apparent trend between cutting height and the cutting hand ulnar deviation: as the height increases, ulnar deviation increases.

In conclusion, this study confirms the finding of the pruning study that the VSP system is the best system from an MSD standpoint, and the VSP 4x4 and the Lyre systems are the least desirable systems. This information has been disseminated in the Napa and Sonoma counties and beyond through industry publications and newsletters, and we will continue to communicate these important findings to vineyard operators in the coming years (Specific Aims #6-8).

STUDY 4- ERGONOMIC OBSERVATIONAL SURVEYS

INTRODUCTION

An ergonomic observational method (Rapid Entire Body Assessment-REBA) was also obtained on a large number of workers during pruning and harvest seasons (Hignett and McAtamney, 1997; Hignett and McAtamney, 2000). This method called for a trained observer to rate the postural load and activity levels of workers while performing repetitive tasks (Figure 56). The rater observes the worker (commonly through a video record) and assigns scores for each body joint based on the angle that the joint is assuming. Each body part receives a score, along with an overall score for the right and left sides. From an MSD standpoint, tasks that have scores exceeding "8" are considered high-risk, and tasks that have scores below "3" are considered low-risk (see Figure 56).

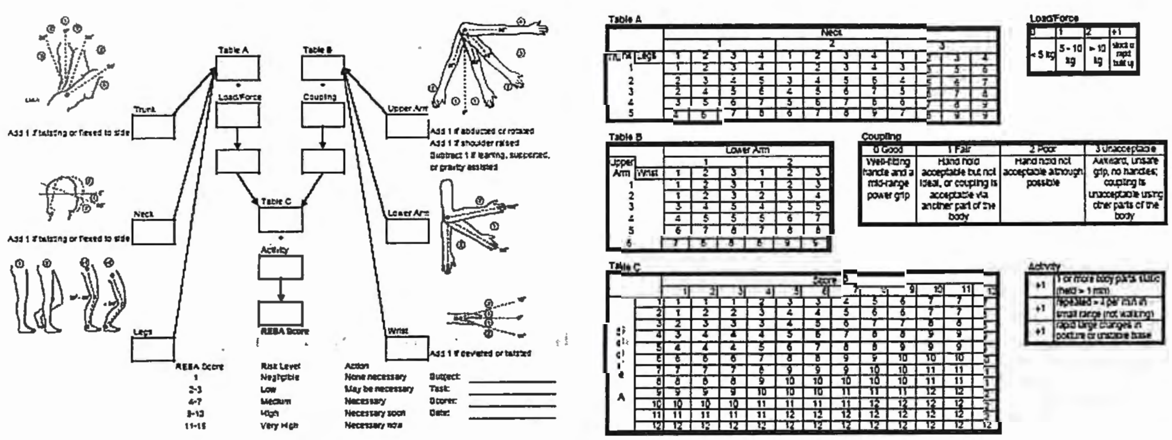


Figure 56. Example of REBA worksheets. From (Hignett and McAtamney, 2000)

PARTICIPANTS AND PROCEDURE

Video records of 91 workers (60 were performing pruning tasks; 31 harvesting) were utilized to obtain REBA scores of potential MSD risks to various body parts. All participants consented to participate voluntarily, and agreed to be videotaped. One rater was trained by one of the co-investigators, Mr. Ira Janowitz, to score these video records. The investigators assured that the rater was consistent in scoring worker postures and activities. The trellis systems included Lyre, VSP, VSP 4x4 and Smart Dyson. Further productivity measures (cuts/second for pruning and cycle time in minutes for harvesting) were also obtained for a subset of these workers.

RESULTS AND DISCUSSION

Figure 57 shows the overall REBA scores, the trunk scores, as well as the upper arms scores during the pruning tasks performed by the workers in the field on the four trellis systems.

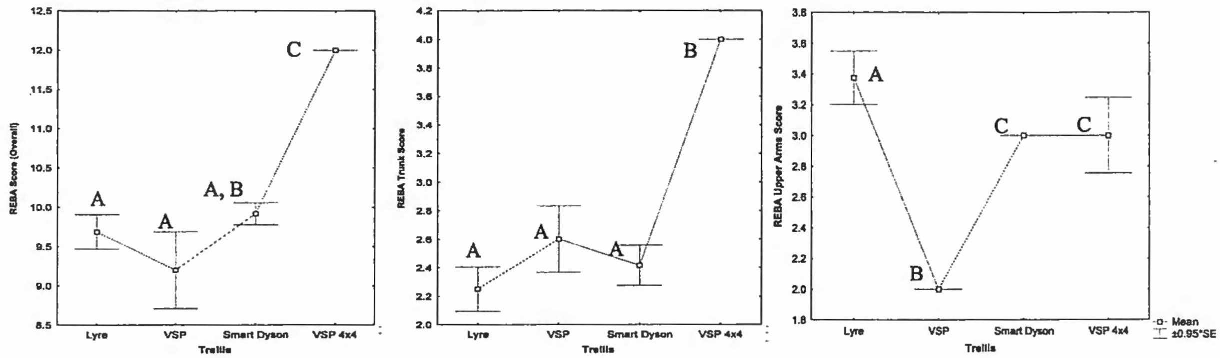


Figure 57. Average REBA scores for each trellis system during **pruning:** a) overall, b) trunk, and c) upper arms. Pairs of conditions with dissimilar letters are significantly different from each other (LSD, $p < 0.05$).

Similarly Figure 58 shows the overall REBA scores, the trunk scores, as well as the upper arms scores during the harvesting tasks performed by the workers in the field on the four trellis systems.

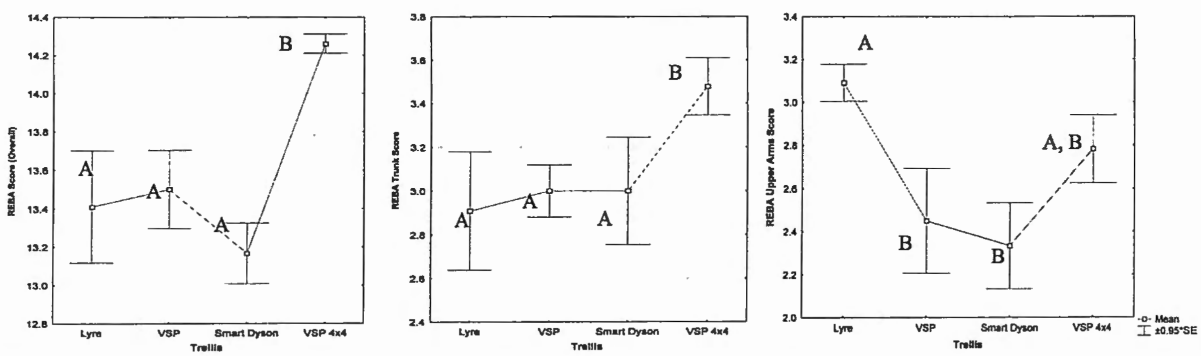


Figure 58. Average REBA scores for each trellis system during **harvesting:** a) overall, b) trunk, and c) upper arms. Pairs of conditions with dissimilar letters are significantly different from each other (LSD, $p < 0.05$; $p < 0.1$ Upper Arms).

The results of this field observational study confirm the findings of the controlled biomechanical/quantitative studies conducted for the pruning and harvesting tasks (Studies 1&2 above). It emphasizes that even though the MSD risk of the back for the lyre system may appear lower than the other systems; this system poses increased risk on the upper arms/shoulders. Note that the Lyre system could make workers assumes trunk extension (bend backwards), which has been shown to be detrimental to the spine.

Another issue that should be explored in terms of the trellis systems is how the trellis design affects worker productivity. For the four field-observed trellis systems, Figure 59 and Figure 60 show the average number of cuts per minute during pruning, and the average cycle time during harvesting, respectively.

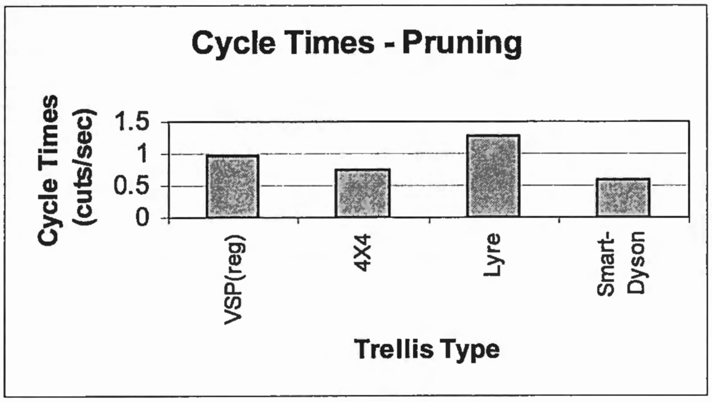


Figure 59. Average cuts/sec during pruning.

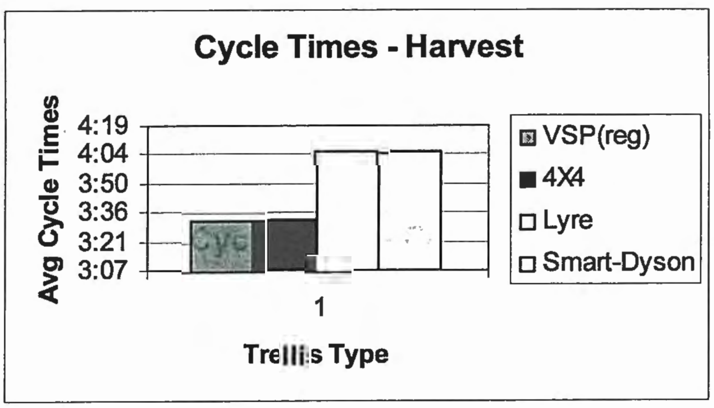


Figure 60. Average cycle time (in minutes) to pick, lift, and dump a full grape tub.

From these figures it is apparent that the Lyre system requires a high cutting rate combined with a long harvest cycle times. The Smart Dyson also required a long cycle time, which could be due to its complicated design (grape clusters are spread both vertically and horizontally along the trellis system; Figure 8)

STUDY 5- COMPARISON OF MSD SYMPTOMS AMONG TRELLIS SYSTEMS: FIELD SURVEYS

INTRODUCTION

MSD symptom and fatigue questionnaires were administered to vineyard workers during the pruning and harvest seasons of 2002 (see Appendix C). The attempt was to obtain symptom surveys on workers who perform these tasks exclusively on trellis systems identified by this study. However, this was not possible because most workers rotate between trellis systems throughout the season.

PARTICIPANTS

A total of 108 workers from several cooperator vineyards were interviewed on multiple occasions. The breakdown of participants within each of the three systems during the pruning and harvesting seasons is shown in Table 18.

Table 18. Number of participants by task and trellis system.

	TASK		
SYSTEM	***Pruning***	***Harvesting***	**Total**
LYRE	21	8	**29**
VSP	29	17	**46**
VSP 4x4	23	10	**33**
Total	**73**	**35**	**108**

MSD Questionnaire

The survey questionnaire is a Spanish questionnaire compatible with the cultural, linguistic, and educational characteristics of mostly Mexican field workers who have immigrated to work in California (Faucett et al., 2001). The interview uses previously tested measures of pain severity, location, and duration and includes items to assist with determining the work-relatedness of the symptoms. The FACES Scale, for example, initially validated for measuring pain among multicultural pediatric populations, was chosen by agricultural workers to evaluate their pain severity. Similarly, the body diagram used to indicate pain location is one commonly used by other researchers investigating musculoskeletal discomfort and has been used before by Dr. Faucett, but the symptoms to be identified are those suggested by the agricultural worker population.

The Spanish translation of the interview has undergone extensive forward and backward translation to ensure the appropriateness of the vocabulary and syntax for agricultural workers from the population to be evaluated.

PROCEDURE

During year 2, MSD symptom surveys were administered to workers during the pruning and harvesting seasons in several vineyards. The workers pruned and harvested three of the five commonly used trellis systems: the Lyre, the VSP, and the VSP 4x4 systems. This was done since these systems exhibited the most difference in terms of MSD risk factors during the pruning and harvest simulation studies discussed earlier, as well as for practical reasons since our cooperators own these types of systems and had a very limited or no acreage of the other systems. The questionnaire was administered at the completion of either pruning or harvesting a given trellis system (typically 1-3 hours).

RESULTS AND DISCUSSION

The symptoms response from the workers was rather low (Table 19). The pain and fatigue scores were also very low and did not have enough data for reporting. The prevalence seemed to be rather low in general when compared to other surveys that our group and others have conducted in the past. This may be due to many factors such as time of the day, time of the season, and the manner in which the survey was administered. In order to capture the effect of trellis design on MSD symptoms, the survey was administered at the end of either pruning or harvesting a given trellis system (e.g. Lyre), rather then the end of the working day. Therefore, it is conceivable that many of the workers were surveyed before their pain and symptoms were fully developed, and hence the low response rate. For example, if workers started their workday by pruning a Lyre system for one hour, and moved onto another system, the symptoms for the Lyre system would have been based on the first hour of their work. Note that workers very commonly rotate among trellis systems.

Table 19. Results of the MSD symptom surveys during pruning and harvesting.

	Pruning			Harvesting		
	4 x 4	VSP	Lyre	4 x 4	VSP	Lyre
Body Part	*N* = 23	*N* = 29	*N* = 21	*N* = 10	*N* = 17	*N* = 8
Right hand	0	0	0	0	0	0
Left hand	0	0	0	0	0	0
Right shoulder	0	0	0	0	0	0
Left shoulder	0	0	0	0	0	0
Right knee	0	0	0	4	4	0
Left knee	0	0	0	4	2	0
Mid back	0	0	0	2	2	0
Low back	5	2	1	5	3	2

Despite the low symptom and fatigue response rate, it is evident that the VSP 4x4 resulted in the highest low back pain response among this population. This confirms the findings of the simulation studies reported earlier.

Note that it was difficult to obtain meaningful OSHA and other injury records to discern the reporting patterns by trellis system. This is, again, because workers rotate among various trellis systems on daily, weekly, and monthly bases.

In conclusion, this study fulfills **Specific Aim #4** and corroborates the findings of Specific Aim 3, and helps in accomplishing aims 5-7.

GENERAL DISCUSSION AND STUDY OUTPUT

The studies presented above contributed to achieving most of the specific aims outlined in the project (**Specific Aims #1-4, 9**). One of the aims of the study was to facilitate use of information about risk factors for musculoskeletal disorders associated with most commonly used winegrape trellis systems in trellis decision-making. This aim was achieved through a two-stage results and conclusions dissemination strategy. The first stage involves presentations at industry meetings where results and conclusions can be interactively discussed with industry leaders and decisionmakers. Work on this goal continues.

Other project aims (**Specific Aims #5-7**) were to develop practice and design parameters for reducing ergonomics risk factors associated with most used trellis systems. In general, we have been most concerned with risks involving awkward postures, heavy loads, and highly repetitive handwork. Initial observation has suggested that differences in trellis systems have greatest impact on working postures, and have little to no impact on repetition or load weights. The method utilized here, was a basic engineering design process proceeding from determination of the "problem" or deficiency of the trellis system in question, through analysis and trial of alternative correction strategies, to implementation and evaluation.

Initially, it was thought that some design parameters for each trellis system (e.g., wire height) might be defined and subjected to alteration in order to significantly reduce identified ergonomics risk exposures. However, on study of the trellis systems with viticulture and industry experts, it became clear that such design modifications, if sufficient to overcome identified ergonomics hazards, would also impair the trellis' planned cultivation performance. As a result, the effort to develop practice and design parameters for alteration was abandoned. Instead, the focus will be on providing information about the importance of the study findings to the industry and most importantly to vineyards that are considering replanting or expanding their winegrape acreage.

Cooperating wineries and vineyard companies and their workers received information on the project and its results through participation in regular meetings. Other industry audiences were reached during the project by staff presentation at regular industry update meetings and through nine state or national industry presentations. Several industry publications have been published, or are in press, outlining the study's main findings (listed below). Throughout the project, the team met with staff of California OSHA Education and Training and State Compensation Insurance Fund to report on this and other projects and to seek their advice and input.

All of these audiences were provided information on the project in all phases, on fundamental ergonomics information where appropriate, and on project related findings as they became available. The bi-county industry community, consisting of more than 250 wineries, was provided with regular updates on the project by UC Davis Farm Advisors Rhonda Smith and Ed Weber on both individual and community scales. Project investigators also participated annually at regional industry meetings. A statewide Extension publication is planned summarizing the projects results and its implications for trellis selection by vineyard owners and managers.

We feel that the multi-layered dissemination efforts discussed above contributed to achieving the last aims of the study (**Specific Aims # 8&9).** Lastly, one of the project goals, which is related to the aforementioned dissemination aims, is to add to research knowledge about the association of specific agricultural workplace ergonomics risk factors and musculoskeletal disorders and their symptoms. This goal was met through scientific presentation and publication of project findings and results by the investigators. These scientific dissemination efforts will continue over the coming year or more.

The following two sections respectively list the presentations, and publications that have resulted from the study up to this point.

PRESENTATIONS

This is a list of scientific presentations related to this project presented by the project investigators at National and Regional meetings, Universities and other Institutes:

1. UC Division of Agricultural and Natural Resources Enology and Viticulture Work Group Annual Meeting, lecture on "Ergonomic Evaluation of Trellis Systems". March 28, 2001
2. American Society of Agricultural Engineers Annual International Meeting, lecture on "Ergonomic Evaluation of California Winegrape Trellis Systems." Chicago, IL, July 30, 2002

3. Lucien Brouha Work Physiology Symposium, lecture on "The Use of Direct Measurements to Assess MSD Risks in Manual Agricultural Work." Sacramento, CA, September 12, 2002
4. Health and Safety in Western Agriculture Conference, lecture on "Agricultural Ergonomics Research Activities in California", Coeur d'Alene, Idaho, September 18, 2002.
5. Invited lecture on "Ergonomics, Occupational Biomechanics and Musculoskeletal Disorders in Agricultural Environments," at the Agricultural Health and Safety Symposium- Oregon Health Sciences University- March 18, 2002.
6. Invited lecture on "Agricultural Ergonomics Research in California," at the Ohio State University Institute for Ergonomics- Guest Lecture Series- May 31, 2002.
7. 2003 State-of-the-Art Research (STAR) Symposium: Perspectives on Musculoskeletal Disorder Causation and Control, poster presentation on "Ergonomic Interventions in Various California Agricultural Industries." Columbus, OH, May 21, 2003
8. National Occupational Research Agenda Symposium- 2003: Working Partnerships: Applying Research to Practice, lecture on "Risks of Musculoskeletal Disorders in California Winegrape Trellis Systems." Arlington, VA, June 23, 2003
9. Triennial Congress of the International Ergonomics Association, lecture on "Ergonomic Evaluation of Pruning and Harvesting Tasks of Winegrape Trellis Systems." Seoul, Korea, August 26, 2003
10. Health and Safety in Western Agriculture Conference, lecture on "Ergonomics in Agriculture." San Francisco, CA, September 9, 2003
11. Western Occupational Health Conference: Cultivating New Ideas, lecture on "Agricultural/Occupational Musculoskeletal Disorders." Napa, CA, September 18, 2004.
12. University of Michigan/University of California short course on Preventing Disability in the Workplace: Ergonomic Evaluation and Design of Tools, Workstations and Tasks, lecture on "Case Studies: Workplace Design for Prevention of Low Back Pain in Agriculture." South San Francisco, CA, Dec 4, 2003
13. 2004 National Symposium on Agricultural Health and Safety: Creating Partnerships Across Multiple Disciplines, lecture on "Ergonomic Evaluation of California Winegrape Trellis Systems." Keystone, CO, June 23, 2004

PUBLICATIONS

Journals

1. Kato, A. E., F. A. Fathallah, J. A. Miles, J. M. Meyers, J. Faucett, I. Janowitz, and E. G. Garcia. Ergonomic evaluation of pruning California winegrape trellis systems. Submitted for publication in the *Journal of Agricultural Safety and Health*.
2. Fathallah, F. A., J. A. Miles, J. Faucett, J. M. Meyers, I. Janowitz, A. E. Kato, E. Garcia, D. A. Reiter, B. J. Miller, and D. G. Tejeda. Ergonomic evaluation of harvesting of winegrape trellis systems. To be submitted to *Journal of Agromedicine*.

Thesis

1. Kato AE: Ergonomic evaluation of California winegrape trellis systems, MS Thesis, University of California, Davis, 2002.

Conference Proceedings

1. Kato, A. E., and F. A. Fathallah. 2002. Ergonomic evaluation of California winegrape trellis systems. Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting, Santa Monica, CA, pp. 1162-1166.
2. Kato, A. E., F. A. Fathallah, E. Garcia, J. A. Miles, J. M. Meyers, J. Facucett, and I. Janowitz. 2002. Ergonomic evaluation of California winegrape trellis systems. American Society of Agricultural Engineers Paper Number 02-8014.
3. Fathallah, F., J. Miles, J. Meyers, J. Faucett, I. Janowitz, E. Garcia, J., A. Kato, and D. Reiter. 2003. Risks of musculoskeletal disorders in California winegrape trellis systems. Abstract, Proceedings of the National Occupational Research Agenda Symposium - 2003: Working Partnerships: Applying Research to Practice, Arlington, VA, p. 46.
4. Fathallah F.A., J.A. Miles, J. Faucett, J.M. Meyers, I. Janowitz, A.E. Kato, E. Garcia, J. D.A. Reiter, B.J. Miller, and D.G. Tejeda. 2003. Ergonomic evaluation of pruning and harvesting tasks of winegrape trellis systems. Proceedings of the Triennial Congress of the International Ergonomics Association. Paper Number T37-Volume 1.

Magazines and Newsletters

1. Fathallah, F.A. in press. Study finds trellis height influences musculoSkeletal disorder risks in vineyards. *Practical Winery and Vineyard* Magazine.

2. Fathallah, F.A. 2004. Study finds trellis height influences MSD risks in vineyards. Resource: Magazine of the American Society of Agricultural Engineers, 11(7), pp. 7-8.

3. UC Center for Occupational and Environmental Health. 2003. Trellis Height Influences MSD Risks in Vineyards, Study Finds. Center's Newsletter, June 2003

4. *Cal-OSHA Reporter*. 2003. Vertical Trellises Best for Vineyard Pruning, UC-Davis Researcher Finds. Volume 30 (25).

5. Western Center for Health and Safety. 2003. Study finds trellis height influences MSD risks in vineyards. Center's Newsletter Volume 12 (4).

6. *Engineering Progress*. 2002. Is one man's Zinfandel another man's pain? UC Davis College of Engineering Publication, Volume 24 (Fall/Winter), pp11-12.

7. *Grape* Magazine. 2002. Keep workers, and their backs, in mind. April 2002 issue.

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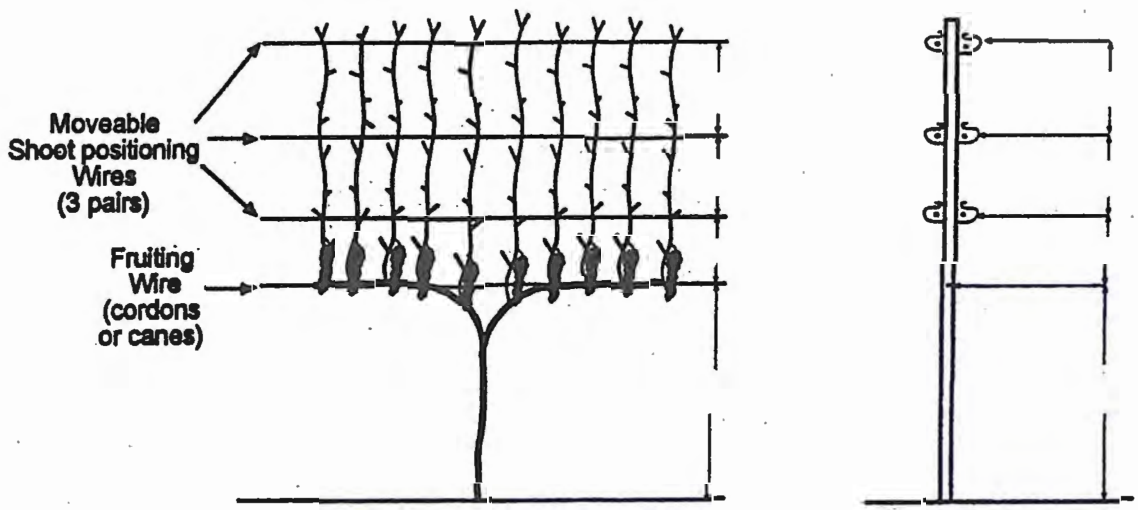
APPENDIX A- PILOT FIELD SURVEY FORM-EXAMPLE

DATE:
TIME:

VINEYARD____________________ GRAPE TYPE____________________

TRELLIS TYPE________________ PRUNING METHOD________________

Vertically Shoot Positioned Trellis



SPACE BETWEEN ROWS___________ SPACE BETWEEN VINES___________

LENGTH OF ENTIRE ROW________ NUMBER OF SHOOTS PER VINE_______

OVERALL TRELLIS HEIGHT___________

IRRIGATION TUBING HEIGHT (IF APPLICABLE)___________

IRRIGATION MATERIAL_____________

SLOPE OF TERRAIN (⊇ - mild, moderate, extreme)___________

TEMPERATURE___________

CYCLE TIME_____________ CUTS/VINE______________

REMOVAL OF BRANCHES (manual, mechanical or unremoved)______________

WORKERS/CREW______________ PRUNER TYPE________________
*Additional Observations on Back

APPENDIX B- CONSENT FORM

CONSENT TO PARTICIPATE IN RESEARCH STUDY
UNIVERSITY OF CALIFORNIA, DAVIS

TITLE OF STUDY: California Vineyard Ergonomics Partnership Project
INVESTIIGATORS (NAME, DEPARTMENT, PHONE NUMBER):
John A. Miles, Biological and Agricultural Engineering Department, UC Davis, 530/ 752-6210; James Meyers, School of Public Health, UC Berkeley, 510/ 642-8375; Fadi Fathallah, Biological and Agricultural Engineering Department, 530/ 752-1612; Edward Weber, Viticulture Farm Advisor, Napa Count, 707/ 253-4221; Linda Garcia, Associate County Director, Sonoma County, 707/ 527-2621; Rhonda Smith, Viticulture Farm Advisor, Sonoma County, 707/ 527-2621

PURPOSE:
You are being asked to participate in a research study. We hope to learn if redesigned tools and systems will make your job safer and easier without decreasing your productivity or reducing the quality of your work.

PROCEDURES:
If you decide to volunteer, we will provide you tools and training in the use of these tools. We will observe your activities as you learn to use these tools. We may ask you to go back to using conventional tools and methods on some days so that we can compare our new systems with current procedures. We will provide questionnaires for you and encourage feedback in other ways so that we may use your input and opinions about our new systems and how they may be modified to make your job easier, safer, and/or more productive.

RISKS:
We are attempting to improve the health and safety of agricultural workers, but many of the normal risks associated with field work will remain. The greatest risk will be during the learning period when you are still unfamiliar with new tools. You will not be under any pressure to work quickly until you are comfortable with these tools. Since this is a research study and the procedures are relatively new, there may be additional side effects which are not know or predictable at this time, but which may occur at the time of procedure or later.

BENEFITS:
No direct benefits may be given to you.

CONFIDENTIALITY:
The data collected in this study may be published in both professional journals and trade journals, but the names of individual workers will not be disclosed. Absolute confidentiality cannot be guaranteed, since research documents are not protected from subpoena. The confidentiality of the records will be maintained to the fullest extent provided law.

COSTS/COMPENSATION:
The University is working in cooperation with your employer, who will provide compensation for your time spent on this project. If you are physically injured as a direct result of research procedures not done primarily for your own benefit, you will receive medical treatment at no cost. The University of California does not provide any other form of compensation for injury.

RIGHT TO REFUSE OR WITHDRAW:
You may refuse to participate. Your decision to participate or not will not affect your employment. You may change your mind and quit after the study has started. The investigator has the right to withdraw subjects for the study at his/her discretion.

QUESTIONS:
If you have any questions, please ask us. If you have additional questions later, John A. Miles will answer them at the Biological and Agricultural Engineering Department, University of California, Davis, (530) 752-6210.

You will be given a signed and dated copy of this form to keep. You will also be given a copy of the Experimental Subject's Bill of Rights.

****

YOUR SIGNATURE BELOW WILL INDICATE THAT YOU HAVE DECIDED TO VOLUNTEER AS A RESEARCH SUBJECT AND THAT YOU HAVE READ AND UNDERSTAND THE INFORMATION PROVIDED ABOVE AND THE BILL OF RIGHTS.

________ ______________________________________
Date Signature of participant or legal representative

________ ______________________________________
Date Signature of Investigator

APPENDIX C- SYMPTOM SURVEY

TRELLIS HARVEST 2002 QUESTIONNAIRE Subject number:________

Interviewer initials:_______ Time & date of interview:__________________
Worker's preferred language: Check one: English______ Spanish_______
What was worker doing during or just prior to the interview:____________________________
Trellis Type #1:______Hrs of work today on trellis #1: Start time:_________ End time:__________
Trellis Type #2:______Hrs of work today on trellis #1: Start time:_________ End time:__________
Trellis Type #3:______Hrs of work today on trellis #1: Start time:_________ End time:__________
Trellis Type #4:______Hrs of work today on trellis #1: Start time:_________ End time:__________

INTERVIEWER - HAVE AVAILABLE:

1. Copies of the FACES scales in Spanish and English
2. Copies of the BODY DIAGRAM and colored pens in yellow, red, blue for the body diagram.

DRAFT SPANISH HEALTH QUESTIONNAIRE

Nuestro equipo de investigación de la Universidad de California quisiera ayudar a los trabajadores para que mejoren su estado de salud. Para poder hacer esto, estamos preguntándole a algunos trabajadores acerca de sí mismos y de cómo se sienten físicamente. Nos interesa especialmente conocer las molestias físicas que sienten día a día, aquí en al trabajo y también en la casa. Estamos seleccionando trabajadores - gente como usted - para preguntarles acerca de esas molestias. Para que podamos ayudar a todos los trabajadores en este trabajo, es muy importante que usted nos cuente acerca de sus molestias físicas, aunque le parezcan de poca importancia o sean diferentes a lo que sienten las demás personas. Nos interesa especialmente saber más acerca de sus dolores persistentes, dolores agudos y molestias que siente en sus músculos, articulaciones o nervios.

Hoy quisiera hacerle varias preguntas acerca de las molestias de sus músculos y esqueleto, que siente ahora o que ha sentido anteriormente. Yo no le voy a decir a nadie en su trabajo qué es lo que usted me ha contado. A nuestro equipo le interesa solamente conocer su opinión. Las preguntas no tienen respuesta correcta ni respuesta equivocada - se trata de su opinión solamente. La información que usted me dé servirá para que nuestro equipo de investigación pueda ayudar a **todos** los obreros, para que puedan trabajar en una forma más saludable. ¿Le parece bien si le hago estas preguntas? ¿Sí? Bueno, entonces empecemos.

Our UC research team wants to help workers improve their health. To do that, we are asking some workers to tell us more about themselves and how they feel physically. We are especially interested in what physical discomforts are experienced day to day here at work and at home. We're selecting workers, such as yourself, to ask about such discomforts. For us to help everyone at this worksite, it is very important that you tell us what physical discomforts you feel even if they seem minor to you or different from what everyone else may experience. We particularly want to know more about your physical aches and pains, those discomforts that you feel in your muscles, joints, or nerves.

Today I want to ask you several questions about the musculoskeletal discomforts that you feel now or have felt in the past. The personal information that you give me won't be shared with anyone else associated with your job. Our team is only interested in your opinion - there are no right or wrong answers to any of the questions. The information you give me will help our research team to help everyone work in a healthy way. Is it all right with you to ask you these questions? Then, let's begin:

USE SECTIONS A, B & E ON FIRST DAY OF SUBJECT ENROLLMENT ONLY:

SECTION A:
Ahora quisiera preguntarle acerca de la clase de trabajo que hace aqui.
Now I'd like to ask you about the kind of work you do here.

1) ¿Cuántos años tiene trabajando en VINEYARD WORK en California? Números de años_____
For how many years have you worked in VINEYARD WORK in California?

2) ¿Cuántos años tiene trabajando para esta companía? Años_____
Meses_____
For how many years have you been working for this company? ***[Enter total #years & months]***

3) ¿Cuántos años tiene trabajando WITH THIS WORK CREW? Números de años_____
or
For how many years have you worked with this work crew? Numeros de semanas____ *Or number of weeks, if just this year*

4) ¿Cuántas horas trabajo ayer o en su ultimo día de trabajo en la VINEYARD? Numero de horas_____
How many hours did you work on your last work day in the VINEYARD?
(NOTE: this may be yesterday.)

SECTION B:
Ahora, quisiera hacerle algunas preguntas personales:
Now, I'd like to ask you some personal questions:

5) ***Interviewer: Circle gender of subject*** Sexo masculino = 1 Sexo femenino = 2

6) ¿Cuántos años tiene? Número de años _____
How old are you?

7) ¿De cuál pais (región o ciudad) viene usted o su familia? City/Country__________________
From what region or city do you or your family come?
Interviewer: write in the name of the Mexican city that best represents the city or region of origin of the family. For countries other than Mexico, write in the name of the country.

8) ¿Cuántos años completó en la escuela? Número de años _____
How many years of school did you complete?

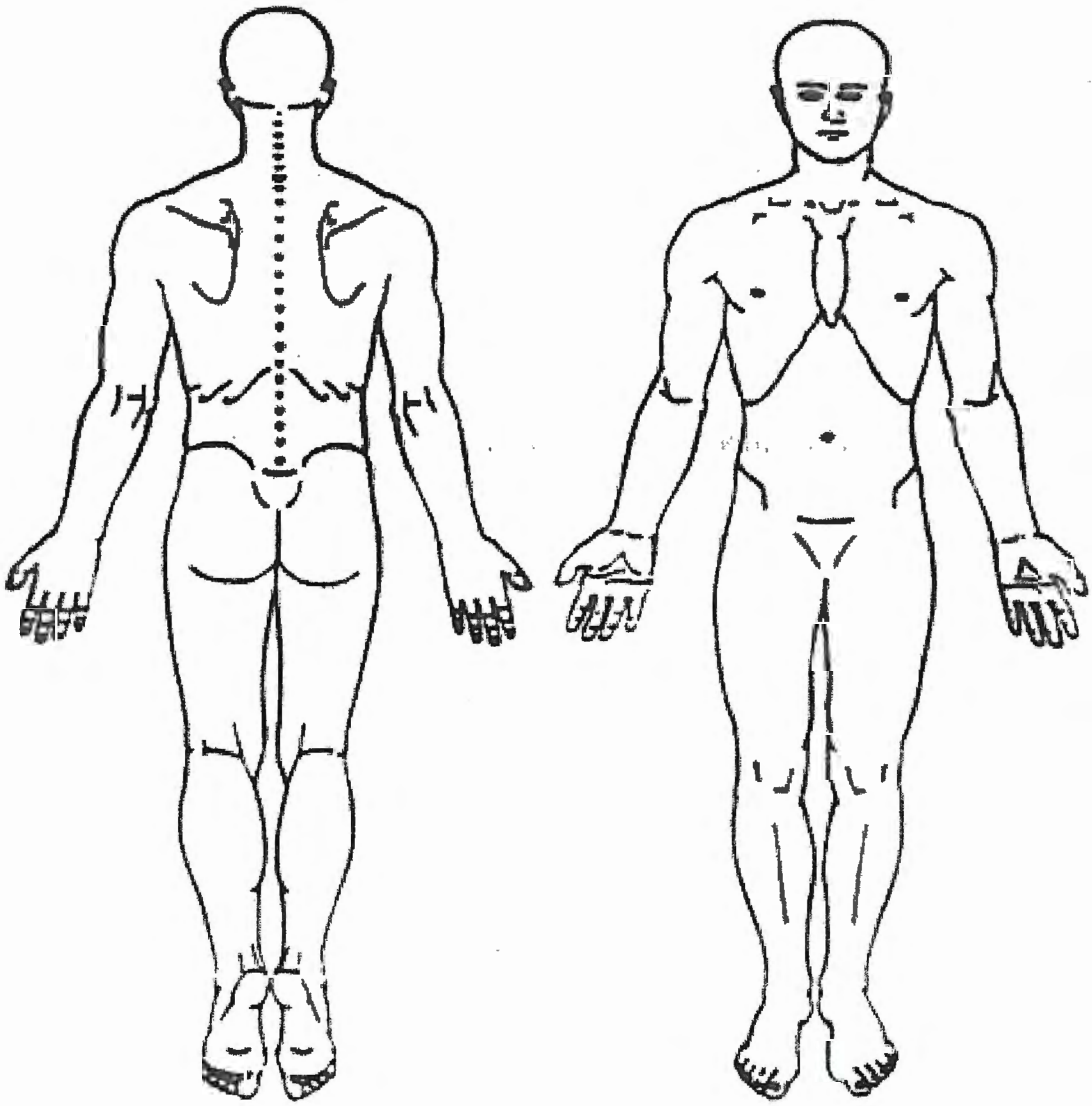
9) ¿Durante cuántos años ha estado viviendo (or worked) en los Estados Unidos?Número de años _____
How many years have you lived or worked in the United States?

USE REMAINING SECTIONS FOR ALL DAYS OF DATA COLLECTION:

Section C: EL DIBUJO DEL CUERPO

Ahora, por favor use el dibujo del cuerpo marca los lugares donde ha tenido dolores agudos, dolores persistentes en sus musculos, huesos o nervios HOY - ***NOW AT THE END OF THE WORK DAY***
Please use the body drawing to OUTLINE the places where you've had aches and pains or discomfort in your muscles, bones, or nerves TODAY - now at the end of the work day.
[SEE BODY DIAGRAM: HAND ALL COLORED PENS TO SUBJECT AND READ ALL THREE ITEMS ABOUT THE COLORS AT THE SAME TIME (SO THAT WORKER HEARS THEM ALL BEFORE COLORING. WORKER MUST DO OWN COLORING]

Marca con el color azul en regiones que Usted tiene un dolor sordo y que no se quita.
Marca con el color rojo en regiones que Usted tiene un dolor fuerte o agudo.
Marca con el color amarillo en regiones que Usted tiene hormigueo o adormecido.



SECTION C

(10) SCORING THE BODY DIAGRAM: Use the plastic overlay to identify the body segments outlined by the worker. Be sure to examine the back of the body in addition to the front, follow the order of segments listed on this page, and examine every segment individually. Examine each segment that falls within the worker's outline for each color (blue, red, and yellow). Circle the "1" if the segment is included, check (v) the zero if the segment is not included in the worker's outline. For colored outlines that overlap only slightly (or ambiguously) with an additional body segment, check the additional segment if you can actually see white space between the margin of the body segment on the plastic overlay and the more distant margin of the colored line made by the worker. In general, if the width of the pen traveling along a segment's border or jutting over a border is the only color visible within a new segment, do not check that segment.

BODY SEGMENT	PROJECT COORDINATOR			DATA CHECKER		
	BLUE	RED	YELLOW	BLUE	RED	YELLOW
FRONT SIDE OF BODY						
Rt foot/shin	0 1	0 1	0 1	0 1	0 1	0 1
Rt knee	0 1	0 1	0 1	0 1	0 1	0 1
Lt foot/shin	0 1	0 1	0 1	0 1	0 1	0 1
Lt knee	0 1	0 1	0 1	0 1	0 1	0 1
Front torso (hips to collar bone)	0 1	0 1	0 1	0 1	0 1	0 1
Rt hand	0 1	0 1	0 1	0 1	0 1	0 1
Rt forearm	0 1	0 1	0 1	0 1	0 1	0 1
Rt elbow	0 1	0 1	0 1	0 1	0 1	0 1
Rt shoulder	0 1	0 1	0 1	0 1	0 1	0 1
Lt hand	0 1	0 1	0 1	0 1	0 1	0 1
Lt forearm	0 1	0 1	0 1	0 1	0 1	0 1
Lt elbow	0 1	0 1	0 1	0 1	0 1	0 1
Lt shoulder	0 1	0 1	0 1	0 1	0 1	0 1
Front of neck	0 1	0 1	0 1	0 1	0 1	0 1
Front of head/face	0 1	0 1	0 1	0 1	0 1	0 1
BACK SIDE OF BODY						
Back of head	0 1	0 1	0 1	0 1	0 1	0 1
Back of neck	0 1	0 1	0 1	0 1	0 1	0 1
Rt shoulder	0 1	0 1	0 1	0 1	0 1	0 1
Rt elbow	0 1	0 1	0 1	0 1	0 1	0 1
Rt forearm	0 1	0 1	0 1	0 1	0 1	0 1
Rt hand	0 1	0 1	0 1	0 1	0 1	0 1
Lt shoulder	0 1	0 1	0 1	0 1	0 1	0 1
Lt elbow	0 1	0 1	0 1	0 1	0 1	0 1
Lt forearm	0 1	0 1	0 1	0 1	0 1	0 1
Lt hand	0 1	0 1	0 1	0 1	0 1	0 1
Mid-back incl. upper spine	0 1	0 1	0 1	0 1	0 1	0 1
Low back across both sides	0 1	0 1	0 1	0 1	0 1	0 1
Rt hip/buttock	0 1	0 1	0 1	0 1	0 1	0 1
Rt knee	0 1	0 1	0 1	0 1	0 1	0 1
Rt foot/calf	0 1	0 1	0 1	0 1	0 1	0 1
Lt hip/buttock	0 1	0 1	0 1	0 1	0 1	0 1
Lt knee	0 1	0 1	0 1	0 1	0 1	0 1
Lt foot/calf	0 1	0 1	0 1	0 1	0 1	0 1

SECTION D

Piense en los lugares que usted emozo con el color AZUL. Estas preguntas son solamente para los dolores o molestias que marcó con el color AZUL. *Think about the places that you colored with BLUE. These questions are only for the discomforts or pains you indicated with the color BLUE.*

Interviewer: Point to sections of body diagram that subject has colored using blue.

(11) ¿Cuál fue la gravedad de este dolor **HOY**?
What was the severity of this pain TODAY?
[USE FACES scale on clipboard] Face #_____

Piense en los lugares que usted embozo con el color ROJO. Estas preguntas son solamente para los dolores o molestias que marcó con el color ROJO. *Think about the places that you colored with RED. These questions are only for the discomforts or pains you indicated with the color RED.*

Interviewer: Point to sections of body diagram that subject has colored using RED.

(12) ¿Cuál fue la gravedad de este dolor **HOY**?
What was the severity of this pain TODAY?
[USE FACES scale on clipboard] Face #_____

Piense en los lugares que usted embozo con el color AMARILLO. Estas preguntas son solamente para los dolores o molestias que marcó con el color AMARILLO. *Think about the places that you colored with YELLOW. These questions are only for the discomforts or pains you indicated with the color YELLOW.*

Interviewer: Point to sections of body diagram that subject has colored using YELLOW.

(13) ¿Cuál fue la gravedad de este dolor **HOY**?
What was the severity of this pain TODAY?
[USE FACES scale on clipboard] Face #_____

[NEEDS TRANSLATION]
Now please think about how tired or fatigued you feel at the end of the work day.

(14) ¿Cuál fue la gravedad de su fatiga HOY? Face #_____
What is the severity of your fatigue today?
[USE: FACES scale on clipboard - ALTER FACES Scale description to mean FATIGUE]

[Interviewer: Read each phrase and circle the number indicated by the worker].

Circule el número que más indica como se siente hoy. Por ejemplo, suponga que no haya comido desde ayer. ?Qué número circularía para el siguiente par de frases?

No tengo nada de hambre	0	1	2	3	4	5	6	7	8	9	10	Tengo mucha hambre

Probablemente circularías un número más cerca a la frase "tengo mucha hambre" al final de la línea. Aquí es donde yo la pondría. Ahora favor de completar las siguientes frases:

[Interviewer - enter the number selected by the worker:]

Circule el número que más indica como se siente TODAY.

15	no tengo nada de energía 0 1 2 3 4 5 6 7 8 9 10 tengo mucho energía *not at all energetic 0 1 2 3 4 5 6 7 8 9 10 extremely energetic*	Number_____
16	no tengo nada de cansancio 0 1 2 3 4 5 6 7 8 9 10 estoy muerta de consancio *not at all tired 0 1 2 3 4 5 6 7 8 9 10 extremely tired*	Number_____
17	no soy nada de activa 0 1 2 3 4 5 6 7 8 9 10 soy muy activa *not at all active 0 1 2 3 4 5 6 7 8 9 10 extremely active*	Number _____
18	no soy nada de eficiente 0 1 2 3 4 5 6 7 8 9 10 soy muy eficiente *not at all efficient 0 1 2 3 4 5 6 7 8 9 10 extremely efficient*	Number_____

SECTION E: General health and utilization of health care services

(19) En general, ¿diría usted que su salud es excelente, muy buena, buena, regular o mala?
In general, would you say your health is excellent, very good, good, fair or poor?

(Interviewer: check one answer)

Excellent_____
Very good____
Good _____
Fair _____
Poor _____

20) En los últimos 12 meses, ¿ha cansultado a un médico debido a sus síntomas o molestias?
In the last 12 months have you consulted a doctor because of your discomforts or symptoms?
Interviewer: If NO, enter date as zeros. If YES, enter the date of the visit if a single visit, or, if there were several visits during an episode, enter the date of the first visit:
___/___/___

21) ¿El médico pudo diagnosticarle su problema? ¿Cuál fue ese diagnóstico?
Was the doctor able to diagnose your problem? What was that diagnosis?

____

22) Segun el médico, ¿cuál fue la causa de sus síntomas o molestias?
What was the cause of your discomforts or symptoms according to the doctor?

____

Interviewer: Check if physician indicated diagnosis was work-related: ______

23) Is there any other information you would like to give us about the trellis system you have worked on today or other aspects of the grape harvesting task?

____

____

THANK YOU TAKING THE TIME TO ANSWER OUR QUESTIONS TODAY!