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EVALUATION OF OCCUPATIONAL CARRYING TASKS FOR FARM YOUTH

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ABSTRACT

Injuries to farm children are unique because of the types of tasks involved, the developmental issues regarding the etiology of the injury, and the potentially severe consequences of the injury. Parents often begin to involve their children in agriculture by assigning them farm maintenance and livestock feeding activities because they are deemed safer than the more complex and hazardous operation of tractors and field equipment or having direct contact with livestock. These tasks may require children to carry loads that are proportionally large and/or heavy and are often unilaterally loaded. The nature of these activities may put children at risk for acute injury or may compromise the musculoskeletal development of the child. There are currently no data available to help parents gage the risks associated with these load carriage tasks or to identify appropriate carrying procedures or limits based on the developmental level of their children.

This project measured and evaluated 73 subjects in four age groups while performing a controlled carrying task. The age groups were 8-10, 12-14, 15-17 and adult. The adult group was the control group including subjects over 18 years of age. An extensive set of anthropometric measurements was collected and used in developing a set of appropriate body segment inertial parameters to complete a geometric model. A set of retro-reflective markers were placed on the body to collect the kinematic information needed for this study.

A load carriage task was performed using a large five-gallon (18.93 l) bucket (29.84 cm diameter x 34.92 cm height) and a small one-gallon (3.78 l) bucket (20.32 cm diameter x 16.51 cm height).The task was performed with unilateral and bilateral distribution of a load equal to 0%, 10%, or 20% of subject's body weight (BW). In the unilateral loading conditions, subjects carried a bucket containing a load of 0%, 10%, or 20% (BW) in their dominant hand. In the bilateral loading condition, subjects carried two one-gallon buckets containing a load of 0%, 5%, or 10% BW in each bucket so that the total load matches that of the unilateral loading condition. Three repetitions of each bucket carrying condition were performed for a total of eighteen trials per subject. The subject walked in a straight in line along the 6-m walkway across force platforms to a designated target. Kinetic data was collected simultaneously with the kinematic data.

The maximum joint torques normalized to body mass were significantly dependent upon age group ($p < 0.01$) and carrying condition ($p < 0.01$). In contrast, maximum joint torques did not display significant dependence upon the interaction between age group and carrying condition ($p = 0.92$). Maximum shoulder abduction torques were significantly higher for adults as compared to the 8-10 year ($p < 0.01$) and 15-17 year ($p = 0.04$) age groups. The adults age group shoulder abduction torques were not significantly higher than the 12-14 age group ($p = 0.12$) In addition, maximum L5/S1 lateral bending torques were significantly higher for the 12-14 year ($p < 0.01$), 15-17 year ($p < 0.01$), and adults ($p < 0.01$) as compared to the 8-10 year age group. The maximum elbow flexion ($p < 0.01$), shoulder flexion ($p < 0.01$), shoulder abduction ($p < 0.01$), shoulder external rotation ($p < 0.01$), L5/S1 lateral bending ($p < 0.01$), and L5/S1 axial rotation ($p < 0.01$) torques were significantly higher when carrying a unilateral small 20% BW bucket as compared to bilateral small 20% BW buckets. In addition, maximum shoulder abduction ($p < 0.01$), L5/S1 lateral bending ($p < 0.01$), and L5/S1 axial rotation ($p = 0.05$) torques were

significantly higher when carrying a unilateral small 10% BW bucket as compared to bilateral small 10% BW buckets.

Several general conclusions may be drawn from this study. The higher loads carried (20% BW) in this study appear comparable to load levels associated with increased risk of lower back disorders found in previous studies. If it is practical in a field setting to carry lower amounts of weight (10% BW), then six of the seven maximum upper extremity/low back torques were significantly reduced. However, there was no evidence that carrying guidelines as a percentage of body weight should be lower for the 8-10 year old group. In addition, if it is feasible to split a load for bilateral carrying, then six of seven maximum joint torques were significantly reduced. However, modifying the carrying task by using smaller one-gallon buckets only produced significant reductions in maximum L5/S1 lateral bending torques.

Several initial carrying guidelines may be inferred from this study. First, the recommendation to scale the amount lifted to the individual's body weight is implicit in this study. At ten and twenty percent body weight, the 8-10 year olds did not have proportionally higher joint torques. Second, it is recommended that buckets be carried bilaterally when possible. Splitting a carried load between two buckets resulted in substantially lower shoulder abduction and L5/S1 lateral bending torques for all age groups. In addition, future analyses may want to consider the effects of age and carrying condition on the loading of the lower extremities. While the youngest subjects appeared to hold their upper body rigid while carrying heavy buckets, an increase in out-of-plane motion of the lower extremities was observed.

HIGHLIGHTS AND SIGNIFICANT FINDINGS

The goal of this project was to investigate potential risk factors for farm children performing occupational carrying tasks. Recommendations for how a bucket carrying task could be modified to reduce the torque requirements on the upper body by lowering the amount of weight in the buckets, using smaller buckets, and bilateral carrying of the buckets were the expected results. Highlights and significant findings in support of this goal are given below.

Does a five-gallon bucket (the container most commonly used in agricultural work settings) inappropriately force children to alter posture to accommodate the dimensions of the bucket and this postural adjustment adversely affect loading on upper extremity joints and the spine? An initial hypothesis was based on the physical size differences between age groups. The hypothesis was that maximum normalized shoulder abduction and L5/S1 lateral bending torques would be proportionally higher in the 8-10 year old group as compared to adults. This hypothesis was not supported and in fact, the opposite results were observed. Maximum normalized shoulder abduction and L5/S1 lateral bending torques were significantly higher in adults than in 8-10 year olds. Higher shoulder abduction and L5/S1 lateral bending torques were predicted in 8-10 year olds on the premise that the loaded buckets would introduce a larger moment arm as a percentage of body size. While surprising initially, the results indicate that the 8-10 year olds were able to compensate for their smaller anthropometry through altered posture and technique.

Will joint loading be lower using a smaller container (one-gallon) that minimizes postural adjustments? It was hypothesized that the maximum normalized shoulder abduction torques would be lower when using one-gallon buckets as compared to five-gallon buckets because of the smaller diameter and children having arms of shorter length than adults. This hypothesis was not supported since maximum normalized shoulder abduction torques were not significantly dependent upon bucket size. Although a larger bucket would move the center of the carried load further away from the body, the research participants are believed to have adjusted their posture to avoid increased shoulder abduction torques. One way that this could be achieved is through increased lateral bending of the trunk, which would reduce the moment arm between the carried load and the shoulder joint. The fact that L5/S1 lateral bending torques were statistically higher when carrying the five-gallon bucket would appear to support this explanation.

Will joint loading and postural adjustment be decreased when a load is distributed bilaterally in smaller dimension containers (i.e., carrying a bucket in each hand)? The hypothesis that the maximum normalized L5/S1 lateral bending torques would be lower when carrying the load bilaterally as compared to unilaterally was tested. This hypothesis was supported since L5/S1 lateral bending torques were statistically significantly higher with unilateral bucket carrying than with bilateral carrying.

Several initial carrying guidelines may be inferred from this study. First, the recommendation to scale the amount lifted to the individual's body weight is implicit in this study. At ten and twenty percent body weight, the 8-10 year olds did not have proportionally higher joint torques. Second, it is recommended that buckets be carried bilaterally when possible. Splitting a carried load between two buckets resulted in substantially lower shoulder abduction and L5/S1 lateral bending torques for all age groups.

TRANSLATION OF FINDINGS

The outcomes of this study adds to the knowledge base to assist parents to identify appropriate lifting and carrying limits for children and adolescents. These research findings will strengthen the information presented in the North American Guidelines for Children's Agricultural Tasks for lifting tasks and could assist in the development of another guideline for carrying animal feed in buckets or other tasks that use buckets.

The advantages of using one-gallon instead of five-gallon buckets were not distinct to make recommendations at this time. The upper body was not used by the children and adolescent subjects to compensate for the size difference between the two bucket types and therefore the expected increases in forces were not observed. The youngest subjects appeared to hold their upper body rigid while carrying the heavy buckets. This action was observed to give an increase in out-of-plane motion of the lower extremities. Future analyses may want to consider the effects of age and carrying condition on the loading of the lower extremities. The children's postural adjustment in the lower extremities may place them at risk for acute or chronic injuries.

Second, the recommendation is to scale the amount lifted to the individual's body weight. At ten and twenty percent body weight, the children did not have proportionally higher joint torques. Using twenty percent body weight as a maximum amount of weight being carried and with working loads using less than twenty percent, children and adolescents are not expected to develop acute or chronic elbow, shoulder, and spine injuries.

Lastly, it is recommended that buckets or other carrying devices be carried bilaterally when possible. The characteristic of dividing the load equally and carrying it balance between both sides of the body reduces the forces and stress on the body. Splitting a carried load between two buckets resulted in substantially lower forces and stress for all age groups. A reduction that children and adolescents will develop acute or chronic elbow, shoulder, and spine injuries is expected using these techniques.

OUTCOMES/RELEVANCE/IMPACT

Three outcomes of this study will assist parents to identify appropriate lifting and carrying limits for children and adolescents. First parents should scale the amount lifted to the individual's body weight. By using less than twenty percent body weight, children and adolescents are not expected to develop acute injuries or compromise the musculoskeletal development. Second, parents should insist on all buckets or containers be carried bilaterally when possible. Splitting and balancing a carried load between two buckets or containers results in substantially lower forces and stress for all age groups therefore reducing potential for acute injuries. Lastly, parents should realize that the shape of containers could cause children to alter lower extremities posture and produce undesirable results.

SCIENTIFIC REPORT

BACKGROUND

Agriculture is the second most dangerous occupation in the United States (Rivara, 1985). The agricultural reputation for being the most dangerous industry in the United States based on death rate does fluctuate but remains in the top as documented by the National Safety Council (2006, and 2004). Meyer and Hendricks (2001) estimate more than 2 million youth under 20 years of age are potentially exposed to agricultural hazards annually. Children have the highest rate of fatal injuries per hour of work time of any age group and account for as many as one-third of the reported farm work-related fatalities (Purschwitz and Field, 1990). A farm injury is typically classified as any injury event that limits normal activities for a minimum of four hours and occurs as a result of occupational or recreational activities related to agriculture (Pickett et al., 1995; Gerberich et al., 2001). Agriculture uses about 4% of the child labor force but accounts for 25% of the most severe child work injuries recorded (US GAO, 1998). Pickett et al. (1995) found that overexertion was a frequent cause of injury for children working on farms. Numerous factors play a part in the high number of fatal and non-fatal injuries occurring to farm children.

Children being younger and more inexperienced often do not possess the physical and cognitive skills to safely complete some of the agricultural work tasks they are asked to perform. Likewise, parents often believe their child to be more advanced, physically and cognitively then the average child. Farm parents often begin to involve their children in occupational tasks by assigning them farm maintenance and livestock feeding activities because they are deemed safer than the more complex and hazardous operation of tractors and field equipment or having direct contact with livestock. Animal care tasks do appear to be commonly performed including a variety of activities such as feeding, watering, and cleaning stalls (Marlenga et al., 2001). However, these tasks may require children to carry loads that are proportionally large and/or heavy. In addition, these task are often done by carrying a bucket in one hand causing the child to change the posture to accommodate the size of the container and the weight of the load which may adversely affect loading on upper body joints and the spine. Previous field research has identified that the average weight manipulated by farm youth tends to be higher than the average weight manipulated by adults in industrial settings (Allread et al., 2004). The nature of these load carriage activities may put children at risk for acute injury or may compromise the musculoskeletal development of the child leading to permanent damage.

In 1996, the National Committee for Childhood Agricultural Injury Prevention (NCCAIP) published a National Action Plan towards maximizing the safety and health of all children and adolescents who may be exposed to agricultural hazards (NCCAIP, 1996). An objective identified by the NCCAIP was the establishment of guidelines for children's and adolescents' work in the agricultural industry. In addition, they recommended that research be conducted on risk factors and consequences associated with children and adolescents who participate in agricultural work. The National Institute for Occupational Safety and Health (NIOSH) also identified the need for research to identify risk factors for work-related injuries to children and youth in their special report on Child Labor Research Needs (NIOSH, 1997).

The National Occupational Research Agenda (NORA) published by NIOSH in 1996 identified 21 priority research areas as a framework for systematically addressing the most pressing and promising, occupational safety and health topics (NIOSH, 1996). NORA identified adolescents at work as a research need for special populations at risk. One of the most serious issues for younger workers is sprains and strains due to overexertion (NIOSH, 1996).

Farm youth have described frequent musculoskeletal pain in the upper and lower extremities, trunk, neck and shoulders, although youth typically do not treat or report an injury of this type and no severe cases were noted (Bartels et al., 2000). .In a systematic review of nonfatal farm injuries to children, Reed and Claunch (2000) reported that only one out of 32 studies (Millard et al., 1996) provided incidence rates of chronic injuries in this population. In this study, 51% of 384 survey respondents younger than 19 years of age reported chronic injuries due to a manual task performed on a farm. Four percent of these respondents reported that these injuries lasted for more than one month. These high rates of injury suggest a potentially serious problem but the lack of data reported in the literature is an indication of the inability to present a direct relationship between a given farm task and specific chronic injuries in children. An understanding of potential risks to children performing repetitive farm tasks is possible by examining chronic injuries observed in children in combination with injury data gathered from adults to suggest possible mechanisms for the development of such injuries.

Raffi et al. (1996) considered the combination of repetitive efforts with inadequate resting periods, strong physical exertion, awkward and/or static postures in selecting a sample of adult farm workers for studying injury incidence. They reported a high incidence of carpal tunnel syndrome and microcirculation disorders attributable, in part, to these working conditions.

One such task, load carrying, requires the worker to assume anatomical positions consistent with injury mechanisms described for the upper extremity and spine. The worker may assume a carrying position with the elbow completely extended and the forearm supinated. Furthermore, if the worker carries the load asymmetrically, the spine may experience significant lateral flexion accompanied by lateral pelvic tilt. These conditions place the worker at risk for developing repetitive injuries to the spine, elbow and wrist.

Carrying tasks can place the elbow in a position of hyperextension combined with supination of the forearm. When the arm is placed in this position, the elbow will experience varus/valgus loading and possibly internal/external rotation loading. Tyrdal and Olsen (1998) reported that such loading in this extreme anatomical position increased joint laxity after loading and was responsible for lesions in the anterior joint capsule of the elbow, avulsion of the medial and lateral collateral ligaments. Although these loads were excessive, it is plausible that lower loads applied repeatedly may result in injuries to these same structures.

Further indication of the potential for elbow injury in carrying tasks is evident in the description of onset of pain when the elbow is passively loaded in an extended position. Rose et al. (2000) found that endurance time (defined as the time to which the perception that the pain of sustaining the load prevented them from continuing) was reduced with the elbow extended and as the load increased. Thus muscle pain was a limiting factor for working ability.

A specific repetitive injury, whose mechanism of development is consistent with load carrying and is commonly experienced by children, is osteochondritis dissecans (OCD) (Peterson et al., 1999). Federico et al. (1990) and Stanitski (1994) have indicated that ischemia and repetitive trauma are related to the development of OCD. Repetitive trauma may spur initial development of OCD but the compromised vascularization may have a more significant impact on the child since this may restrict bloody supply to the epiphysis and secondary centers of ossification resulting in compromised bone growth.

Spinal injury, specifically low back pain, is another repetitive injury that can be related to load carrying. Duggleby and Kumar (1997) reported a 30% incidence rate of low back pain in children suggesting that this is another prevalent injury in children. Determining a causal mechanism for low back pain is difficult. Mooney (1987) reported that the majority of low back pain incidences are undiagnosable but Newcomer and Sinaki (1996) concluded that the primary causes of low back pain in children were musculotendinous strains and ligamentous sprains. This does not relate the development of such conditions to specific activities but activities that require large amounts of flexion, lateral flexion, and axial twisting increase the compressive loads in the spine. Of particular note, lateral flexion and axial twisting can produce increases in spinal loading by 75 to 300% over pure flexion tasks (McGill, 1988). Drury et al., (1989) and Mital and Kromodihardjo (1986) offer additional support that asymmetrical loading of the spine in the frontal plane increases compressive and shear forces on the spine.

Summarizing, the anatomical requirements of load carrying place the worker at risk of developing several injuries that could result in lost work time or potentially skeletal developmental problems. The asymmetrical nature of load carrying combined with the use of equipment not properly scaled to children may exacerbate these problems.

Research on load carriage has focused primarily on loads applied to the trunk mainly at the shoulder using backpacks or sidepacks (DeVita et al., 1991). These data suggest that load carriage increases joint loading in the lower extremities (e.g., hip and knee) and that asymmetric application of these loads, such as would be applied with a sidepack, increase the moment at L5/S1 such that an "unbalanced lateral trunk muscle dominance" is developed to counteract the applied external load (DeVita et al., 1991, p. 1119). Therefore, load carriage can result in abnormal loading of the spine. This may suggest that prolonged exposure to such loads may compromise the health of the musculoskeletal regions experiencing these abnormal loads.

These previous studies provide useful information regarding lower extremity kinetics, but they only considered loads applied at the shoulder. In many occupational settings load carriage is accomplished by supporting the load through a hand-held device such as a bucket. This type of load carriage would add stress to the joints of the upper extremity, particularly to the elbow. In an agricultural setting, such load carriage tasks are often performed by children because they are prohibited from performing more skilled tasks that involve the operation of machinery. Evidence exists from literature on youth activity in exercise and sports to suggest that prolonged and/or excessive loading to the elbow may result in permanent developmental changes. For instance, McManama et al. (1985) reported that 6 out of 7 patients that underwent elbow surgery to correct osteochondritis of the capitellum due to repetitive microtrauma were heavily involved in Little League or Pony League Baseball. Lipscomb (1975) maintained that these type of injuries resulted in "varying degrees of traumatic arthritis and permanent joint impairment" (p. 31).

Load carriage in an agricultural setting may present a situation that induces such abnormal loads on a repetitive basis. Typically, these tasks involve the transport of feed to livestock areas. This task is often carried out by using containers to transport the feed that have been used to store and/or ship materials. It has been shown that the container width in the sagittal plane will affect the maximum acceptable weight in load carriage in well-trained males (Morrissey and Liou, 1988). In fact, any dimension that forces a person to carry the object further from the weight bearing joints will increase the loads on these joints and increase the potential for injury. This factor is amplified in children because a 5-gallon bucket will force greater shoulder abduction in a child than it would in an adult. When these containers are carried by children, the postural adjustments include abnormal amounts of shoulder abduction to carry the bucket to the side of the body or abnormal amounts of shoulder flexion to carry the bucket in front of the body. Given that the loads carried in such containers can be heavy and that these loads are applied to the hand, the loads in the upper extremity, particularly the elbow and shoulder, will increase potentially exposing the youth to a higher risk of injury.

When assessing whether motor tasks like load carriage are developmentally appropriate for girls and boys, the interaction of changes in growth (size), physical fitness (e.g., muscular strength and endurance), and motor skills must be considered. Children's ability to perform and control movements in tasks associated with work, leisure, and sport are clearly influenced by growth, fitness, and skill development (Thomas et al., 1993). Children mature at varying rates, especially during puberty, producing normal differences among adolescents of the same age of as much as 100 pounds in weight and over 12 inches in height (Malina, 1975). In addition, bones grow at varying rates resulting in disproportionality in the ratio of limb to torso lengths (e.g., sitting height to standing height) and torso breadths (shoulder width to hip width) (Malina, 1975). These rapid changes in size, when combined with varying levels of muscular development, often result in movements that appear awkward and uncoordinated (Thomas and Thomas, 1988) especially in tasks requiring considerable exertion such as carrying. Thus, age is a poor predictor of skilled behavior. Ample evidence of the failure of age to predict motor expertise has been reported (e.g., Abernethy, 1988; Abernethy et al., 1993; French and Thomas, 1987; McPherson and Thomas, 1989).

Physical fitness levels also vary greatly by developmental level and gender (Thomas and Thomas, 1988; Thomas et al., 1991). Males are generally more active than females at all ages (Eaton and Enns, 1986). For example, in the mile run (reflecting cardiovascular endurance), males run slightly faster than females up to 8 years of age. Differences favoring male performance become greater up to puberty and then differences accelerate after puberty (Ross and Gilbert, 1985; Ross and Pate, 1987; Thomas et al., 1991). Muscular strength and endurance follows a very similar pattern of small differences favoring male performance before puberty with increasingly larger differences following puberty. Flexibility is the only physical fitness measure favoring girls both prior to and following puberty. Besides systematic differences between boys and girls, within gender differences are quite large on fitness measures and are more closely related to size (height and fatness) than to age (Smoll and Schutz, 1990).

For motor skills, changes across childhood and adolescence are related to practice (leading to expertise) rather than to age (Abernethy et al., 1993; Thomas et al., 1993). However, growth impacts motor performance, especially in movement tasks in which size and strength are important (Nelson et al., 1991; Nelson et al., 1986; Thomas et al., 1993). Gender differences are typically found in most motor performance tasks both before, during, and following puberty (Thomas and French, 1985). For most tasks, the pattern is small differences favoring male performance prior to puberty with larger differences developing during and following puberty. The most common explanation for the development of these differences prior to puberty is differential opportunities and encouragement given to males as compared to females. Following puberty, explanations focus on a biological by environmental interaction (Thomas and French, 1985).

Any system developed to assess the types of motor tasks of which children and adolescents are capable, including carrying, must consider all of these characteristics to establish task readiness. In addition, many motor tasks require perceptual and cognitive decision-making that clearly influence performance (Abernethy, 1988; Abernethy et al., 1993; Thomas et al., 1986). Since perceptual and cognitive processing develop over childhood and adolescence (e.g., Kail, 1986, 1988, 1991), this aspect of developmental performance must be considered, especially in motor tasks having time constraints (e.g., requiring rapid decision-making).

SPECIFIC AIMS

Injuries to farm children are unique because of the types of tasks involved, the developmental issues regarding the etiology of the injury, and the potentially severe consequences of the injury. Parents often begin to involve their children in agriculture by assigning them farm maintenance and livestock feeding activities because they are deemed safer than the more complex and hazardous operation of tractors and field equipment or having direct contact with livestock. These tasks may require children to carry loads that are proportionally large and/or heavy and are often unilaterally loaded. The nature of these activities may put children at risk for acute injury or may compromise the musculoskeletal development of the child. Such observations have been made in athletic settings where children exposed to abnormally large loads when pitching have resulted in an increased rate of permanent musculoskeletal injuries including osteochondritis and osteoarthritis. There are currently no data available to help parents gage the risks associated with these load carriage tasks or to identify appropriate carrying procedures or limits based on the developmental level of their children. The following research questions are the driving forces behind this proposed project:

a) Does a five-gallon bucket (the container most commonly used in agricultural work settings) inappropriately force children to alter posture to accommodate the dimensions of the bucket?

b) Does this postural adjustment adversely affect loading on upper extremity joints and the spine?

c) Will joint loading be lower using a smaller container (one-gallon) that minimizes postural adjustments?

d) Will joint loading and postural adjustment be decreased when a load is distributed bilaterally in smaller dimension containers (i.e., carrying a bucket in each hand)?

The goal of this project is to investigate potential risk factors for farm children performing occupational carrying tasks to make recommendations regarding the loading (unilateral vs. bilateral) and the container size used for performing these tasks. In support of this goal, the following objectives have been established:

- Recruit subjects (both male and female) representative of rural Midwestern farm youth.

- Collect anthropometric, kinematic, and kinetic data from the subjects following established experimental protocols.
- Reduce data for further analysis by identifying and editing marker paths, applying an optimized digital filter to reduce the noise in the data, calculating 3-dimensional segment orientations and joint angles, and differentiating the angles to obtain angular velocities and accelerations.
- Combine the kinetic, anthropometric and kinematic information to calculate joint moments, reaction forces, and joint powers using a computer model developed previously in the Iowa State Biomechanics Laboratory.
- Analyze joint moments and powers for carrying tasks using a large and small container with unilateral loading, and using small containers with bilateral loading.
- Develop recommendations addressing the loading condition and the container size for occupational carrying tasks performed by youth.
- Develop educational materials and curriculum based on the recommendations targeting farm parents, farm youth, and safety educators.
- Disseminate the results of the project.

PROCEDURES

Subject Recruitment

The target population for this study was children under the age of 18 in the rural Midwestern United States. This target population will be sampled using children in rural Iowa. The demographic breakdown for the target population and sample population are shown in Table 1 (race) and Table 2 (gender). Four age groups of subjects recruited were; 8-10 years, 12-14 years, 15-17 years, and adult. Table 3 provides gender information for these age groups.

Table 1. Population data by race for Midwest region and Iowa.

Midwest Regional Rural Population (Other Rural)		Iowa Rural Population (Other Rural)	
Race	Percent %	Race	Percent %
White	97.8	White	99.3
Black	0.9	Black	0.1
American Indian	0.8	American Indian	0.2
Eskimo	0.0	Eskimo	0.0
Aleut	0.0	Aleut	0.0
Asian	0.3	Asian	0.2
Pacific Islander	0.0	Pacific Islander	0.0
Other	0.2	Other	0.2
Total	100	Total	100

Table 2. Population data by gender for Midwest region and Iowa.

Midwest Regional Rural Population (Other Rural)				Iowa Rural Population (Other Rural)		
Gender	Population	Percent %		Gender	Population	Percent %
Males (all yrs.)	6,515,065	51		Males (all yrs.)	325,913	51
Females (all yrs.)	6,259,682	49		Females (all yrs.)	307,251	49
Total	12,774,747	100		Total	633,164	100

Table 3. Population data by gender for targeted age groups for Midwest region and Iowa.

Midwest Regional Rural Population (Other Rural)				Iowa Rural Population (Other Rural)		
Gender	Population	Percent %		Gender	Population	Percent %
Males (8-17 yrs. excluding 11)	988,695	52		Males (8-17 yrs. excluding 11)	50,333	52
Females (8-17 yrs. excluding 11)	910,363	48		Females (8-17 yrs. excluding 11)	46,660	48
Total	1,899,058	100		Total	96,993	100

Subjects were recruited from local 4-H clubs by extension county staff to match these demographics including race and gender. Based on the demographics of the target population, 11 males and 11 females were recruited in the four age groups: 8-10, 12-14, 15-17 and adult (18 or over). The target population is almost exclusively white, non-hispanic. However, subjects were also recruited from migrant populations since these youth are also at risk for occupation related injuries and are not represented in the census data.

Subject retention (and therefore drop-out rate) was not be an issue for the experimental design because subjects were required to attend only one data collection session. Therefore, successful recruitment of the required number of subjects to match the prescribed sample will be the primary concern. To assist in recruitment efforts, an incentive of $20 was paid to each subject who participates in the study. Ten dollars was paid to subjects who return for a second session in which additional data are collected for calculation of reliability.

Protocol

During a single visit to the Iowa State University Biomechanics Laboratory participants moved through three stations where different forms of data were collected. Each laboratory visit lasted no longer than two hours per participant with an average of 90 minutes being the norm.

Station #1

This station was used to complete an approved informed consent form, collect demographic information, health history, and occupational history.

Station #2

This station was used to collect an extensive set of anthropometric measurements used in developing a set of appropriate body segment inertial parameters. The literature on inertial properties, particularly in children, is limited. Therefore, a geometric model was developed to predict segment inertial properties based on a method described by Gillette (1999) to provide a consistent method for estimating inertial properties independent of age. This model allows inertial properties to be scaled based on body size and shape. This model required an extensive set of anthropometric measurements. Twenty-six anthropometric measurements (Table 4) were taken from each subject to complete the geometric model. The protocol for taking these measurements was based upon those described in the Anthropometric Standardization Reference Manual (Lohman et al., 1991). Male and female laboratory personnel, trained in the collection of these measurements, were used to collect these data from the male and female participants, respectively.

Station #3

This station was designed to complete the load carriage trials in a controlled setting. Each participant changed in to black lycra shorts and a black sleeveless t-shirt provided by the laboratory. This clothing allowed reflective markers to be placed on the subject without being obscured by loose clothing or being subject to movement artifact. Laboratory personnel then placed retro-reflective markers on the participant using double-sided adhesive disks. The markers were placed on the body to provide the information needed to complete the geometric model for anthropometrics and to appropriately define segment endpoints to be used in the inverse dynamic analysis (see Table 5).

On the upper body, retro-reflective markers were placed on the third metacarpals, mid-wrists, mid-forearms, lateral humeral epicondyles, medial humeral epicondyles, mid-triceps, and acromions. Additional markers were placed on the suprasternale, on the lower back at the L5/S1 intervertebral level, on the greater trochanters, and on the bucket(s). The full marker set was captured during a static posture, and then the medial humeral epicondyle markers were removed so they did not interfere with movement during bucket carrying. Medial humeral epicondyle markers were recreated using the lateral humeral epicondyle, mid-triceps, and shoulder markers during the dynamic trials. These body retro-reflective markers are visible as the white (or bright) reflective spheres shown in Figure 1.

A load carriage task was performed using large (five-gallon) and small (one-gallon) containers. The containers chosen for this study were a five-gallon (18.93 l) bucket (29.84 cm diameter x 34.92 cm height), similar to what is commonly used in an agricultural setting to transport feed from storage to livestock, and a one-gallon (3.78 l) bucket (20.32 cm diameter x 16.51 cm height).

Table 4. Anthropometric data collected for each subject.

Measurement	Description	Measurement	Description
Body Mass	In kg with subject wearing trial apparel	Substernale Breadth	Breadth of torso at substernale
Height	Vertical distance from floor to head vertex	Chest Depth	Depth of chest at nipples
Foot Length	Horizontal length from heel to longest toe	Suprasternale Height	Distance from floor to suprasternale
Foot Breadth	Maximum breadth across metatarsals I-V	Cervicale Height*	Vertical distance from floor to cervical
Ankle Height*	Distance from floor to lateral malleollus	Neck Circumference	Circumference of neck
Ankle Circumference	Ankle circumference at lateral malleollus	Head Circumference	Circumference of proximal to brow ridges
Tibiale Height	Distance from floor to medial tibiale	Upper Arm Length*	Length from acromion to radiale
Tibiale Circumference	Knee circumference at tibiale	Axillary Circumference	Circumference of upper arm below armpit
Greater Trochanter Height*	Vertical distance from floor to trochanter	Elbow Circumference	Elbow circumference over olecranon
Midthigh Circumference	At midpoint of tibaile and trochanter	Lower Arm Length*	Length from radiale to styloin
Superior Iliac Height	Vertical distance from floor to iliac spines	Wrist Circumference	Wrist circumference proximal to stylion
Superior Iliac Breadth	Breadth of torso at superior iliac spines	Fist Length	Length from stylion to third metacarpale
Substernale Height	Vertical distance from floor to substernale	Fist Breadth	Breadth of fist at edge of metacarpals

*These anthropometrics data were determined directly from video data using retro-reflective marker positions

Table 5. Location of retro-reflective body markers.

Segment(s)	Marker Locations	Segment(s)	Marker Locations
Right and left foot	Heels	Right and left upper arm	Acromion
	First metatarsal		Mid-triceps
	Lateral malleolus	Right and left forearm	Lateral humeral epicondyles
Right and left calf	Lateral malleolus		Mid-forearms
	Medial tibiale	Right and left hand	Mid-wrist
	Lateral tibiale		Third metacarpal
Right and left thigh	Medial tibiale	Head	Suprastenale
	Lateral tibiale		
	Greater trochanter	Upper torso	Suprasternale
Lower torso	Right greater trochanter		Right acromion
	Left greater trochanter		Left acromion
	L5/S1 intervertebral level	Bucket(s)	Center of dimensions left and right buckets

The task was performed with unilateral and bilateral distribution of a load equal to 0%, 10%, or 20% of participant's body weight (BW). In the unilateral loading conditions, participants carried either a five-gallon or one-gallon bucket containing a load of 0%, 10%, or 20% (BW) in their dominant hand. In the bilateral loading condition, participants carried two one-gallon buckets containing a load of 0%, 5%, or 10% BW in each bucket so that the total load matches that of the unilateral loading condition. Bucket loads were increased by adding sealed packets of lead shot with a weight of 0.98 N (100 g) to the bucket in a manner that balances the distribution of weight within the bucket. The six carrying conditions were as follows: a.) unilateral large 20% BW, b.) unilateral large 10% BW, c.) unilateral small 20% BW, d.) unilateral small 10% BW, e.) bilateral small 20% BW, and f.) bilateral small 10% BW. Three repetitions of each bucket carrying condition were performed for a total of eighteen trials per participant. The experimental design is given in Table 6. The order of the conditions was balanced across subjects to reduce biasing effects of learning and fatigue.

Each participant was instructed to grasp and lift the bucket(s) with the forearm(s) in a supinated orientation. This orientation was chosen to take advantage of the natural carrying angle created by the asymmetric geometry of the elbow joint. The carrying angle provided each participant, particularly the younger ones, a natural ability to accommodate the wider diameter of the large container. The subject walked in a straight in line along the 6-m walkway across both force platforms to a designated target where the bucket or buckets were returned to the ground. Trials were accepted as good only if each foot completely contacted a single force platform with sequential steps. The bucket was returned to the starting position by laboratory personnel between trials.

Table 6. The nine different conditions that each participant completed for a total of 27 trials per participant.

Unilateral Condition			Bilateral Condition*	
Percent of Body Weight	One five-gallon bucket	One one-gallon bucket	Percent of Body Weight	Two one-gallon buckets
0%	3 Replications	3 Replications	0%	3 Replications
10%	3 Replications	3 Replications	5%	3 Replications
20%	3 Replications	3 Replications	10%	3 Replications

* The percent of body weight for the bilateral conditions refers to the weight carried in each hand, so the overall load carried was the same as the unilateral conditions: 0% BW, 10% BW, and 20% BW.

METHODOLOGY

Three-dimensional position data of the retro-reflective body markers were acquired using an eight-camera, Peak Motus Real-Time system at a nominal rate of 120 Hz and filtered at a 6 Hz cutoff frequency with a fourth-order, low-pass, zero phase-shift Butterworth filter. Infrared lights were attached to each camera and filters were placed on each lens to reduce light frequencies that originate from other sources. Eight cameras were used to ensure that all markers remain visible to at least two cameras throughout the entire trial. The accuracy of a marker location was improved when two or more cameras track it and the use of eight cameras allowed four cameras to record each side of the body. Thus, retro-reflective body markers that disappeared in one camera as the arm or load obscures a marker did not cause a gap in the data. Camera placement was established through pilot work but these positions were refined prior to data collection.

The video capture volume was the space enclosed by the field of vision for the eight-cameras that record the retro-reflective body markers. The eight cameras were arranged in 4.3 meter diameter circle mounted at the ceiling so the video capture space is a 4.3 meters diameter cylinder from the floor to the bottom edge of the cameras.

Kinetic data was collected simultaneously with the kinematic data. Two Advanced Mechanical Technology, Inc. force platforms were used to measure the ground reaction forces under each foot during the carrying trials. These force platforms measured the vertical and two shear components as well as moments about each of the three principle axes. The force platforms were sampled at a rate of 120 frames per second to match the kinematic data. Peak Motus software was used to synchronize collection of force platform and kinematic data. Kinetic data was used to calculate the resultant force, the location of the force vector and the free moment during the trials.

Kinematics were analyzed for the middle 2 meters of the bucket carrying task, which allowed for the capture of one full stride. Wrist joint centers were set at the mid-wrist markers, and elbow joint centers were calculated as the midpoint between the tracked lateral and recreated medial humeral epicondyle markers. Shoulder joint centers were located using the acromion markers and the elbow joint centers according to deLeva's adjustments (1996a). The L5/S1 joint center was located by the position of the L5/S1 marker in the vertical and medial/lateral directions. In the anterior/posterior direction, the L5/S1 joint center was calculated at 68% from the L5/S1 marker to the midpoint of the greater trochanter markers as adapted from de Looze et al. (1992). It was assumed that the hand segment mass centers were aligned with the third metacarpal markers. The forearm, upper arm, and torso segment mass centers were calculated as a percentage of segment length (deLeva, 1996b).

An upper body inverse dynamic model was used to calculate elbow, shoulder, and L5/S1 joint torques. Joint rotations were calculated as three successive rotations (flexion/extension, abduction/adduction, and internal/external rotation) at the elbow, shoulder, and L5/S1 joints. Segment masses were estimated as a percentage of body weight and segment moments of inertia were scaled using segment masses and lengths (deLeva, 1996b). Hand contact forces were calculated by summing the known bucket weight acting vertically downward with the known bucket mass multiplied by the measured bucket acceleration in the anterior/posterior, medial lateral, and vertical directions. The applied moment between the bucket and the hand was assumed to be zero. Joint forces and torques were calculated successively from the wrists to elbows to shoulders to L5/S1 using Newton-Euler equations.

With the capture of one full stride length and small upper body ranges of motion, maximum joint torques were utilized as a measure of highest loading during carrying. Elbow joint torques were transformed to the upper arm coordinate system, while shoulder and L5/S1 joint torques were transformed to the torso coordinate system. The dependent variables were maximum joint torques for elbow flexion, shoulder flexion, shoulder abduction, shoulder external rotation, L5/S1 extension, L5/S1 lateral bending, and L5/S1 axial rotation. To aid in comparisons involving research participants with a wide range of ages and body sizes, maximum joint torques were scaled by body mass. In order to avoid the inclusion of noisy data, trials with marker discontinuities resulting in high angular acceleration (>100 rad/s^2) were eliminated from the analysis. For each research participant, maximum joint torques were then averaged across remaining trials for the six carrying conditions.

Multivariate ANOVA (SPSS, Chicago, IL) was used to test the effects of age group, carrying condition, and their interaction on the maximum normalized joint torques. The significance level was set to $p < 0.05$ with a Bonferroni correction of seven (number of dependent variables). When significant main effects were found, post-hoc tests of multiple comparisons were also made at a significance level of $p < 0.05$ with a Bonferroni correction of seven. The effects of age on maximum joint torques were compared between the four age groups (six possible comparisons). To test the effects of carried weight, two comparisons were possible: unilateral large 20% BW vs. unilateral large 10% BW and unilateral small 20% BW vs. unilateral small 10% BW. Two possible comparisons tested the effects of loading symmetry: unilateral small 20% BW vs. bilateral small 20% BW and unilateral small 10% BW vs. bilateral small 10% BW. Finally, two possible comparisons tested the effects of bucket size: unilateral large 20% BW vs. unilateral small 20% BW and unilateral large 10% BW vs. unilateral small 10% BW.

RESULTS AND DISCUSSION

Sixty-two male and female participants in four age groups (8-10, 12-14, 15-17, and adults) representative of rural mid-west farm population were measured. The adults included in this study provide a reference for an age group that has achieved musculoskeletal and motor skill development. The gender distributions and average participant heights and body masses in each age group are presented in Table 7.

Table 7. Average participant characteristics values plus/minus one standard deviation for height and weight by age group.

Age Group Year	Gender Male : Female	Height (m) ± std. dev.	Mass (Kg) ± std. dev.
8-10	9:5	1.369 ± 0.086	34.8 ± 9.1
12-14	9:7	1.567 ± 0.064	52.8 ± 12.0
15-17	7:7	1.669 ± 0.099	61.0 ± 9.8
Adult	9:9	1.742 ± 0.099	71.2 ± 12.8

The measured anthropometric data are presented in Tables 8 and 9 for 8-10 age group, Tables 9 and 10 for 12-14 age group, Tables 11 and 12 for 15-17 age group, and Tables 13 and 14 for adults age group. Subject numbers that are followed by an "R" indicates those subjects that were brought back for a return visit to collect the data need for the test-retest reliability. The test-retest reliability for measurements data were collected on a separate day within one week of the first data collection.

Although this study was not intended to compare males and females, it should be noted that there were age-dependent difference is participant characteristics. Differences in height ranged from females being 0.6 percent taller in the 12-14 age group to males being 10.5 percent taller in the 15-17 age group. Difference in the mass ranged from females having 1.4 percent greater mass in the 8-10 age group to males have 23.3 percent greater mass in the adult age group.

Three-dimensional kinematic position data of the retro-reflective body markers were acquired. None of the retro-reflective body markers disappeared from all cameras or caused a gap in the data. The retro-reflective body markers were recorded while the subject moved through the video capture volume. The data was used to construct a stick sagittal representation of the participant as shown in Figure 1. An example of the kinetic force platform data that illustrates the ground reaction forces for the participant's left and right foot is shown in Figure 2. The combination of the kinetic and kinematic data using the technique described earlier yields the upper body data used in the statistical analysis.

Three trials of data were analyzed for each subject under each condition. These are the calculation of trial-to-trial reliability. The average inter-trial reliability (three trials) for maximum normalized upper extremity joint torques was 97.7 percent (or 2.3 percent standard deviation).

The maximum joint torques normalized to body mass were significantly dependent upon age group ($p < 0.01$) and carrying condition ($p < 0.01$). In contrast, maximum joint torques did not display significant dependence upon the interaction between age group and carrying condition ($p = 0.92$).

Table 8. Anthropometric Data for 8 to 10 age group Part I

Gender	Subject number	Hand Dominance	body weight (lbs)	height(in)	tibiale height (cm)	superior iliac height (cm)	substernale height (cm)	suprasternale height(cm)	foot length (cm)	foot breadth (cm)	superior iliac breadth (cm)	substernale breadth (cm)	chest depth (cm)
Male	1	R	64.0	54.0	24.6	35.2	26.1	97.0	9.2	20.8	37.7	77.7	21.0
Male	2	R	68.0	50.5	32.0	71.8	95.5	107.6	19.5	8.2	23.0	22.7	15.8
Male	3	R	62.0	50.8	29.6	70.4	89.4	102.3	19.2	7.3	21.2	20.8	18.3
Male	3R	R	63.0	51.0	33.0	71.8	95.0	105.2	19.4	7.1	20.9	20.8	16.3
Male	4	R	97.0	59.0	41.5	85.2	105.9	119.7	22.9	8.3	25.6	23.7	18.3
Male	5	R	56.5	51.0	32.2	72.8	92.5	106.3	20.6	7.5	20.7	21.2	14.4
Male	5R	R	55.6	51.0	33.2	71.1	93.8	107.0	20.6	7.6	20.6	20.7	14.9
Male	6	R	57.8	56.0	38.2	81.8	104.3	118.6	23.3	8.1	24.0	22.2	15.0
Male	7	R	131.0	62.0	47.4	86.0	112.6	127.6	24.7	9.4	29.2	32.1	23.3
Male	8	R	70.2	53.0	33.1	75.6	93.4	105.7	22.3	7.2	22.5	22.6	16.4
Male	9	L	78.5	54.0	34.0	76.5	98.1	112.0	21.2	7.8	23.3	24.1	18.7
Female	10	R	96	56.75	37.4	82.7	103	118.6	22.7	8	25.1	23.4	19.9
Female	10R	R	96	56.75	39.2	83.4	104.4	118.6	22.6	7.6	24.5	23.7	18.6
Female	11	R	75.5	53.5	35.6	78.3	96.5	108.6	21.9	8.2	22.2	22.4	14.8
Female	12	R	66.75	52	36.3	74.4	93.4	106.8	19.8	7.6	19	21.8	15.2
Female	13	R	82	52	34	73.6	92.3	104.3	21.5	7.6	23	21.2	16.4
Female	14	R	65.5	50.5	32.5	73	92.1	101	20.4	7.1	21.7	21.2	14.5

* The "R" after the subject number identifies subjects that were brought back for a return visit.

Table 9. Anthropometric Data for 8 to 10 age group Part II

Gender	Subject number	fist breadth (cm)	fist length (cm)	ankle circumference (cm)	tibiale circumference (cm)	midthigh circumference (cm)	neck circumference (cm)	head circumference (cm)	axillary circumference (cm)	elbow circumference (cm)	wrist circumference (cm)
Male	1	14.6	21.0	110.1	26.4	55.2	22.0	18.5	13.4	7.1	6.4
Male	2	6.4	7.2	43.5	27.5	39.5	29.7	50.3	25.4	19.2	13.6
Male	3	6.7	6.1	20.0	25.0	34.8	27.5	54.7	23.9	19.4	14.3
Male	3R	6.4	9.0	22.0	24.5	35.7	27.0	55.2	21.8	19.4	13.2
Male	4	7.3	7.8	22.7	29.2	43.5	29.8	56.8	27.7	21.0	14.5
Male	5	6.7	8.5	20.7	23.6	35.3	26.0	53.7	20.5	18.3	12.7
Male	5R	6.6	8.6	21.5	23.4	34.7	25.7	53.5	20.3	18.0	12.7
Male	6	7.0	8.8	22.0	27.1	40.3	28.2	55.3	25.2	20.8	14.1
Male	7	8.9	8.5	27.0	40.2	54.0	35.1	57.0	38.7	29.1	19.3
Male	8	6.4	6.8	22.0	27.4	37.2	29.6	54.4	24.3	20.0	14.1
Male	9	6.2	7.8	20.1	27.5	36.5	27.2	51.6	25.3	20.6	13.7
Female	10	6.8	8.6	22.2	30.9	41.1	29.9	56.4	29.9	22.8	15.3
Female	10R	7.3	9.3	23.8	30.7	45.2	28.8	55.7	30.2	22.3	15.2
Female	11	6.8	7.4	22.5	28.4	40.3	28.1	55.0	24.6	21.0	14.2
Female	12	6.8	7.5	21.7	27.9	38.5	28.3	54.0	23.5	19.3	12.8
Female	13	6.4	6.8	22.0	28.1	44.5	28.4	54.7	27.6	21.0	14.0
Female	14	6.2	6.8	23.0	28.1	40.2	26.0	51.5	22.8	18.8	12.7

* The "R" after the subject number identifies subjects that were brought back for a return visit.

Table 10. Anthropometric Data for 12 to 14 age group Part I

Gender	Subject number	Hand Dominance	body weight (lbs)	height(in)	tibiale height(cm)	superior iliac height(cm)	substernale height(cm)	suprasternale height(cm)	foot length(cm)	foot breadth(cm)	superior iliac breadth (cm)	substernale breadth (cm)	chest depth (cm)
Male	19	R	117.5	56.5	37.0	78.0	102.8	118.5	22.5	8.9	28.0	28.6	22.4
Male	20	R	123.5	62.5	44.5	93.5	114.5	131.7	25.3	8.9	29.4	24.2	18.2
Male	20R	R	123.0	63.3	41.8	94.2	116.6	130.0	25.4	8.6	27.4	23.9	18.6
Male	21	R	91.5	61.5	39.5	86.5	115.0	126.0	25.0	8.7	19.3	23.1	14.4
Male	22	R	139.0	61.5	42.7	95.0	111.9	129.1	24.3	8.7	28.7	29.4	19.3
Male	23	R	95.8	66.2	45.1	91.3	109.6	124.4	24.8	8.9	22.2	24.5	17.4
Male	24	L	133.0	63.0	41.0	93.3	115.6	129.8	24.7	9.9	27.8	27.6	20.0
Male	25	R	173.5	63.8	41.8	89.8	113.8	129.4	29.0	10.2	31.7	31.1	23.3
Male	26	R	111.5	60.1	38.8	88.8	112.0	126.5	23.5	9.2	26.5	26.0	19.3
Male	27	R	104.1	62.0	37.8	90.6	112.5	128.1	24.8	9.2	27.3	27.1	18.1
Male	73	R	78	58.5	38.4	85.6	109.7	121.4	21.9	8.9	24.5	23.4	17.7
Male	74	R	105.3	62.3	42.1	93.2	114.3	128.2	25.0	9.6	26.3	26.8	18.4
Female	28	R	91.0	61.5	42.5	90.4	110.5	125.6	23.4	8.6	27.4	24.4	16.4
Female	29	R	76.0	57.3	38.2	83.3	101.8	116.3	21.5	8.0	24.0	22.1	16.1
Female	30	R	100.0	65.5	44.2	98.5	120.2	135.5	25.3	8.0	27.0	24.1	16.9
Female	31	R	120.5	60.0	38.0	85.1	107.4	125.5	20.9	8.3	26.9	25.5	23.4
Female	31R	R	120.5	60.0	38.7	84.0	105.8	123.5	20.9	8.4	25.6	24.8	23.0
Female	32	R	94.5	61.8	39.5	94.8	113.1	128.2	25.2	8.7	26.6	26.7	15.8
Female	33	R	110.0	64.5	42.2	94.2	118.9	134.3	22.4	8.2	26.3	25.0	22.6
Female	34	R	158.3	63.6	39.2	91.1	112.9	134.3	23.5	9.4	29.2	26.7	22.6
Female	35	L	107.5	59.5	40.0	81.8	106.7	122.1	17.2	7.0	25.1	24.5	16.2
Female	36	R	160.0	64.0	44.5	94.6	116.2	128.0	25.4	9.7	34.1	29.5	21.8
Female	75	R	127	65.3	45.1	95.0	112.8	130.7	24.6	8.4	29.0	27.8	18.5

* The "R" after the subject number identifies subjects that were brought back for a return visit.

Table 11. Anthropometric Data for 12 to 14 age group Part II

Gender	Subject number	fist breadth (cm)	fist length (cm)	ankle circumference (cm)	tibiale circumference (cm)	midthigh circumference (cm)	neck circumference (cm)	head circumference (cm)	axillary circumference (cm)	elbow circumference (cm)	wrist circumference (cm)
Male	19	7.5	8.5	24.0	31.4	46.5	32.2	53.3	33.5	23.5	16.5
Male	20	7.3	10.3	24.5	34.2	52.3	31.1	55.6	29.3	23.2	15.3
Male	20R	7.5	9.3	23.7	34.7	50.4	31.7	55.4	30.4	23.7	15.4
Male	21	7.2	10.3	23.3	29.5	40.0	30.5	54.0	28.0	20.3	15.0
Male	22	7.7	9.0	25.2	35.4	53.2	32.2	56.0	32.5	24.3	15.8
Male	23	7.1	10.0	23.3	31.9	43.3	30.5	54.3	26.2	21.4	14.2
Male	24	7.4	6.9	26.0	34.5	50.6	31.4	55.3	32.2	25.3	15.8
Male	25	8.6	9.2	27.8	38.4	51.4	33.6	58.5	38.6	28.9	18.5
Male	26	7.0	10.2	34.4	32.2	47.2	30.0	53.0	29.2	23.5	16.0
Male	27	7.6	9.0	24.5	32.1	41.0	32.0	57.5	27.3	22.5	15.2
Male	73	7.0	8.5	23.1	26.6	37.0	26.8	54.0	23.8	20.4	13.1
Male	74	7.8	8.8	27.0	31.3	42.1	30.5	53.5	27.5	24.0	15.3
Female	28	7.1	8.5	22.8	28.3	41.0	29.8	54.4	27.3	20.9	14.5
Female	29	7.2	7.8	23.2	27.6	39.0	28.8	52.6	25.9	20.2	14.3
Female	30	7.2	8.8	22.1	30.4	39.3	28.1	51.7	29.2	20.8	14.6
Female	31	7.0	9.1	22.2	30.8	53.5	30.2	54.6	31.5	22.2	14.6
Female	31R	7.0	9.3	22.8	29.8	52.8	30.4	54.7	30.7	22.9	14.7
Female	32	7.5	9.5	24.0	28.9	42.8	27.3	52.1	23.8	21.2	14.0
Female	33	6.7	8.2	22.2	30.7	46.9	28.7	54.9	27.3	21.8	14.1
Female	34	7.2	10.1	25.5	39.0	61.7	32.5	52.0	31.3	25.7	16.5
Female	35	5.4	8.5	24.0	31.6	49.8	30.3	55.1	28.2	23.0	15.0
Female	36	7.8	7.6	24.7	36.2	57.3	31.9	58.8	34.2	25.7	15.8
Female	75	7.2	7.9	23.2	33.4	49.1	30.3	56.6	28.3	23.0	14.8

* The "R" after the subject number identifies subjects that were brought back for a return visit.

Table 12. Anthropometric Data for 15 to 17 age group Part 1

Gender	Subject number	Hand Dominance	body weight (lbs)	height(in)	tibiale height(cm)	substernale height(cm)	suprasternale height(cm)	superior iliac height(cm)	foot length(cm)	foot breadth(cm)	superior iliac breadth (cm)	substernale breadth (cm)	chest depth (cm)
Male	37	R	138	67.5	44.3	122.9	140.6	100.3	25.9	10.1	29.4	25.8	19.1
Male	37R	R	142	67.25	45.5	123.6	139.2	99.4	26.4	10	27.2	26.3	19.5
Male	38	R	135.5	66.75	51	124.2	138.5	99.8	27.1	10.1	24.9	28.7	20
Male	39	R	124.25	67.75	43	125.3	144.2	96.7	24.8	9.7	27.5	27.8	21
Male	40	R	178.5	71.25	45	130.1	147.5	99	28	10.7	31.5	34.4	23.9
Male	42	R	161	73.5	47.6	135.4	152.9	109.1	28.3	11.2	30.6	30.7	23.2
Male	43	R	160.5	73	46.5	136.9	153.6	109	28.3	10.3	31.2	32.7	20
Male	44	R	183	70	48.4	129.4	144	103.2	28.8	11.3	32.1	34.7	24.7
Female	46	L	130	66	43.1	116.2	135.2	92.6	24.6	6.7	29.8	26.6	18
Female	47	R	125	64	41.5	115.7	132.9	95.7	23	7.7	27.9	26	18.5
Female	48	R	120.5	62.25	37.9	110	128.2	88.2	23.4	8.8	27.4	26.6	20.9
Female	49	R	145.5	63.75	43.1	114	133.2	92.5	22.3	8.5	29.8	28.4	23.2
Female	50	R	143.5	63.25	39.5	118.2	135.1	92.5	25.2	10.2	32.5	27.6	28.3
Female	51	R	103	61.25	36.9	109.6	126.9	85.4	22.2	9.2	25.9	25.5	17.7
Female	52	R	105.5	61.25	38.1	111.9	126.9	87.4	22.5	8.8	29.9	26.1	18
Female	53	R	182	69	46.4	121.6	142	103.9	25.7	9.5	34.4	32.5	22.7

* The "R" after the subject number identifies subjects that were brought back for a return visit.

Table 13. Anthropometric Data for 15 to 17 age group Part II

Gender	Subject number	fist breadth (cm)	fist length (cm)	ankle circumference (cm)	tibiale circumference (cm)	midthigh circumference (cm)	neck circumference (cm)	head circumference (cm)	axillary circumference (cm)	elbow circumference (cm)	wrist circumference (cm)
Male	37	8.5	9	25.6	32.2	48.7	34.2	55.5	35.4	25.4	16.8
Male	37R	8.5	10.2	27.5	32.4	52.6	33.7	55.6	34	25.2	17
Male	38	8.6	10.5	27.7	35.8	50.7	36	56.8	35	24.1	17
Male	39	7.4	11.2	25.4	32.5	46.2	33	56.4	28.8	24	16.2
Male	40	9.7	10.5	28.4	35.7	52.5	39.6	59.4	36.4	27.5	18.5
Male	42	10.2	10.5	29	35.2	50.1	36.2	57.1	32.8	26.3	17.6
Male	43	8.9	10.4	27.4	34.6	49.5	34.4	58	32.1	27.6	17.1
Male	44	9.4	8.6	26.6	38.5	51.4	38.4	57.6	38.2	29.3	18.3
Female	46	7.7	8.9	24.3	32.7	50.1	32.4	53.1	32.8	22.7	15.7
Female	47	7.3	8.7	24.2	32.2	50.5	30.3	54.4	32.4	23	15.2
Female	48	7.4	11	23	32.8	51.9	31.1	54.8	29.4	21.9	15
Female	49	6.9	10.8	23.6	34.6	61	32.8	54.6	29.6	23.4	15.5
Female	50	7.9	9.1	24.8	33.6	56.1	32	58.1	32.2	23.9	14.9
Female	51	7.2	8.6	22	30.6	45.1	29.8	55	27.3	21.5	14.4
Female	52	7.7	9	22.3	28.5	45.8	30	52.3	29.2	21.6	14.1
Female	53	7.9	8.3	24.1	39	59.1	32	57.7	34.9	26.6	15.7

* The "R" after the subject number identifies subjects that were brought back for a return visit.

Table 14. Anthropometric Data for adult age group Part I

Gender	Subject number	Hand Dominance	body weight (lbs)	height (in)	tibiale height (cm)	foot length (cm)	foot breadth (cm)	superior iliac height (cm)	substernale height (cm)	superior iliac breadth (cm)	substernale breadth (cm)	chest depth (cm)
Male	55	R	138.0	70.3	49.1	29.3	9.4	104.1	131.0	28.0	25.9	20.4
Male	55R	R	137.0	70.3	46.6	29.2	9.4	103.7	130.0	26.7	26.2	19.7
Male	56	R	148.3	70.5	46.6	29.5	9.6	102.1	130.0	30.3	31.1	20.3
Male	57	R	186.3	71.5	47.1	29.6	10.0	108.1	130.3	31.3	31.9	22.6
Male	58	R	174.0	74.0	52.4	29.2	9.6	106.6	134.7	31.0	31.0	20.6
Male	59	R	218.0	69.3	42.4	28.5	10.2	93.9	122.7	34.8	33.4	25.8
Male	60	R	164.8	71.0	49.9	30.5	10.6	110.6	132.9	30.4	29.7	23.9
Male	60R	R	161.8	71.0	50.7	30.4	10.4	109.5	133.5	30.8	29.7	24.2
Male	61	R	159.0	73.0	51.0	28.3	9.5	105.6	133.1	31.4	29.4	22.6
Male	62	R	195.0	70.5	44.7	27.3	9.0	100.0	125.4	29.3	31.0	21.3
Male	63	R	190.0	74.5	51.8	27.6	10.2	104.5	134.0	28.6	26.4	21.7
Female	64	R	171.0	69.5	42.7	28.6	9.3	97.5	125.3	29.2	27.2	20.4
Female	65	R	128.0	62.0	41.0	26.0	9.5	88.8	109.1	27.4	25.9	20.3
Female	66	R	139.5	67.0	44.3	26.2	9.1	100.8	122.9	31.2	25.5	22.4
Female	67	L	153.0	65.3	44.0	27.9	9.2	95.1	118.5	30.4	26.8	21.3
Female	68	R	122.0	64.5	41.7	23.1	8.4	93.5	114.1	24.6	22.6	17.7
Female	69	R	119.0	63.0	43.4	25.4	9.1	93.6	113.8	27.9	26.4	20.3
Female	70	R	128.5	67.0	46.2	26.6	9.4	97.0	120.7	27.3	28.0	19.9
Female	71	R	128.0	65.5	44.5	25.9	9.5	94.0	118.7	29.7	25.6	20.5
Female	72	R	157.0	66.3	43.0	26.7	9.1	94.3	116.1	29.8	30.0	22.5

* The "R" after the subject number identifies subjects that were brought back for a return visit.

Table 15. Anthropometric Data for adult age group Part II

Gender	Subject number	suprasternale height (cm)	fist length (cm)	fist breadth (cm)	ankle circumference (cm)	tibiale circumference (cm)	midthigh circumference (cm)	neck circumference (cm)	axillary circumference (cm)	elbow circumference (cm)	wrist circumference (cm)
Male	55	149.3	11.2	7.6	25.5	33.0	51.3	32.5	32.1	24.6	15.3
Male	55R	147.0	11.5	7.4	25.0	33.7	50.4	32.4	31.1	24.0	15.2
Male	56	149.2	11.9	8.6	25.7	32.3	49.3	36.3	36.2	26.6	17.3
Male	57	153.5	10.7	8.8	25.7	33.7	52.5	39.0	38.2	28.2	17.5
Male	58	155.3	12.0	8.3	25.1	32.8	54.0	36.8	37.3	27.1	17.5
Male	59	141.8	10.6	8.4	26.1	37.9	61.2	39.4	38.8	29.4	17.5
Male	60	153.7	12.2	8.0	24.6	33.0	54.1	36.9	35.6	25.5	16.2
Male	60R	152.9	11.0	8.1	23.5	33.2	54.5	36.5	37.4	26.0	16.3
Male	61	153.8	11.2	7.6	25.4	32.8	51.4	33.3	34.5	25.5	15.7
Male	62	143.8	9.5	8.5	23.0	35.7	56.4	41.4	40.4	27.6	17.8
Male	63	153.4	9.8	7.8	24.8	38.5	56.8	36.2	35.4	26.9	16.0
Female	64	141.1	10.5	7.1	25.1	38.5	58.9	33.7	33.4	25.8	16.7
Female	65	132.0	10.2	7.0	22.3	31.6	56.5	30.0	32.0	22.6	14.0
Female	66	138.7	10.0	7.1	22.2	32.5	56.0	31.2	30.4	21.3	14.1
Female	67	137.5	10.0	7.0	24.7	33.7	55.4	32.3	34.5	23.5	14.8
Female	68	132.0	9.0	6.7	19.8	30.6	51.0	30.9	31.5	23.0	14.3
Female	69	133.0	9.0	7.2	22.4	31.0	51.3	28.7	30.5	22.2	14.5
Female	70	138.0	10.0	7.5	23.8	30.3	53.3	30.0	29.3	22.5	14.5
Female	71	136.5	11.0	7.9	23.8	31.7	54.9	30.8	30.0	22.6	15.5
Female	72	138.8	10.8	7.8	24.5	34.6	59.1	32.5	33.8	25.6	15.8

* The "R" after the subject number identifies subjects that were brought back for a return visit.

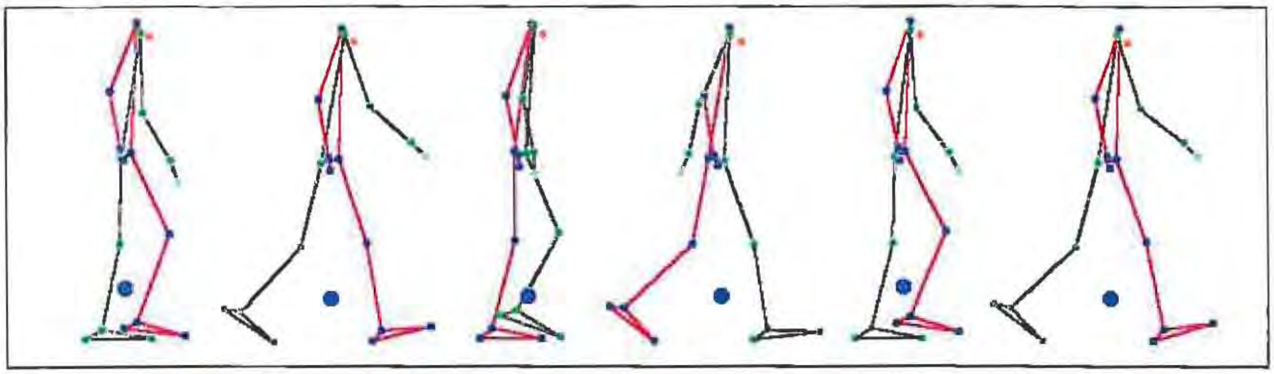

Figure 1. Example of retro-reflective body marker data transformed to subject in motion.

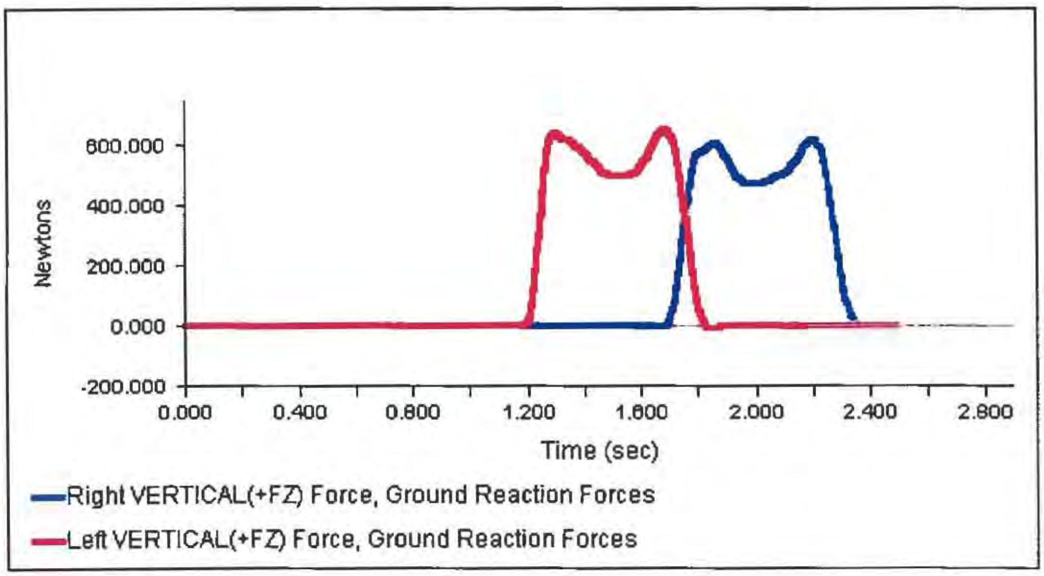

Figure 2. An example of the kinetic force platform data.

Effects of Age Group

Maximum shoulder abduction torques were significantly higher for adults as compared to the 8-10 year ($p < 0.01$) and 15-17 year ($p = 0.04$) age groups (Figure 3). The adults age group shoulder abduction torques were not significantly higher than the 12-14 age group ($p = 0.12$) In addition, maximum L5/S1 lateral bending torques were significantly higher for the 12-14 year ($p < 0.01$), 15-17 year ($p < 0.01$), and adults ($p < 0.01$) as compared to the 8-10 year age group (Figure 4). Differences in maximum elbow flexion, shoulder flexion, shoulder external rotation, L5/S1 extension, and L5/S1 axial rotation torques between age groups were not statistically significant ($p = 0.22$ and higher for all comparisons).

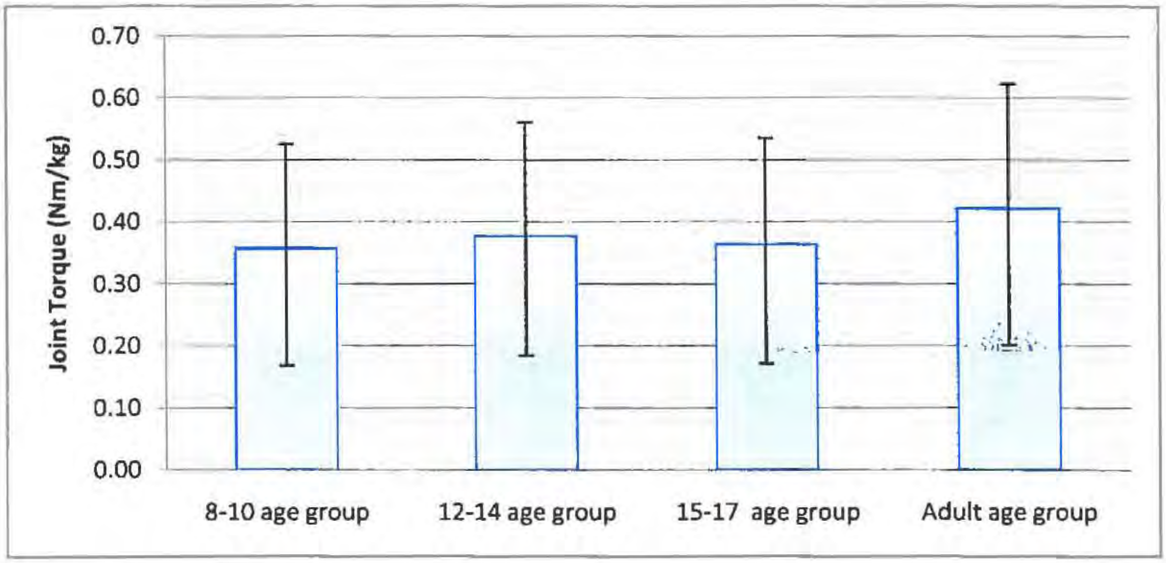

Figure 3. Maximum joint torques as a function of age group for shoulder abduction.

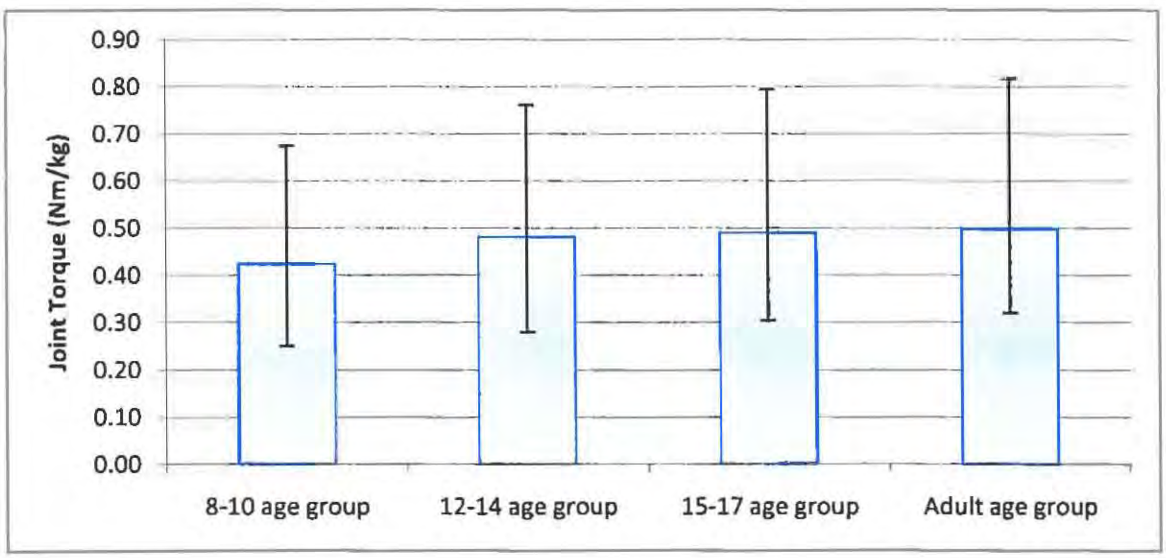

Figure 4. Maximum L5/S5 lateral bending torques as a function of age group.

Effects of Weight Carried

Maximum elbow flexion ($p = 0.02$), shoulder flexion ($p < 0.01$), shoulder abduction ($p < 0.01$), shoulder external rotation ($p < 0.01$), L5/S1 lateral bending ($p < 0.01$), and L5/S1 axial rotation ($p < 0.01$) torques were significantly higher when carrying a unilateral large 20% BW bucket as compared to a unilateral large 10% BW bucket (Figure 5). Maximum elbow flexion ($p = 0.01$), shoulder flexion ($p < 0.01$), shoulder abduction ($p < 0.01$), shoulder external rotation ($p < 0.01$),

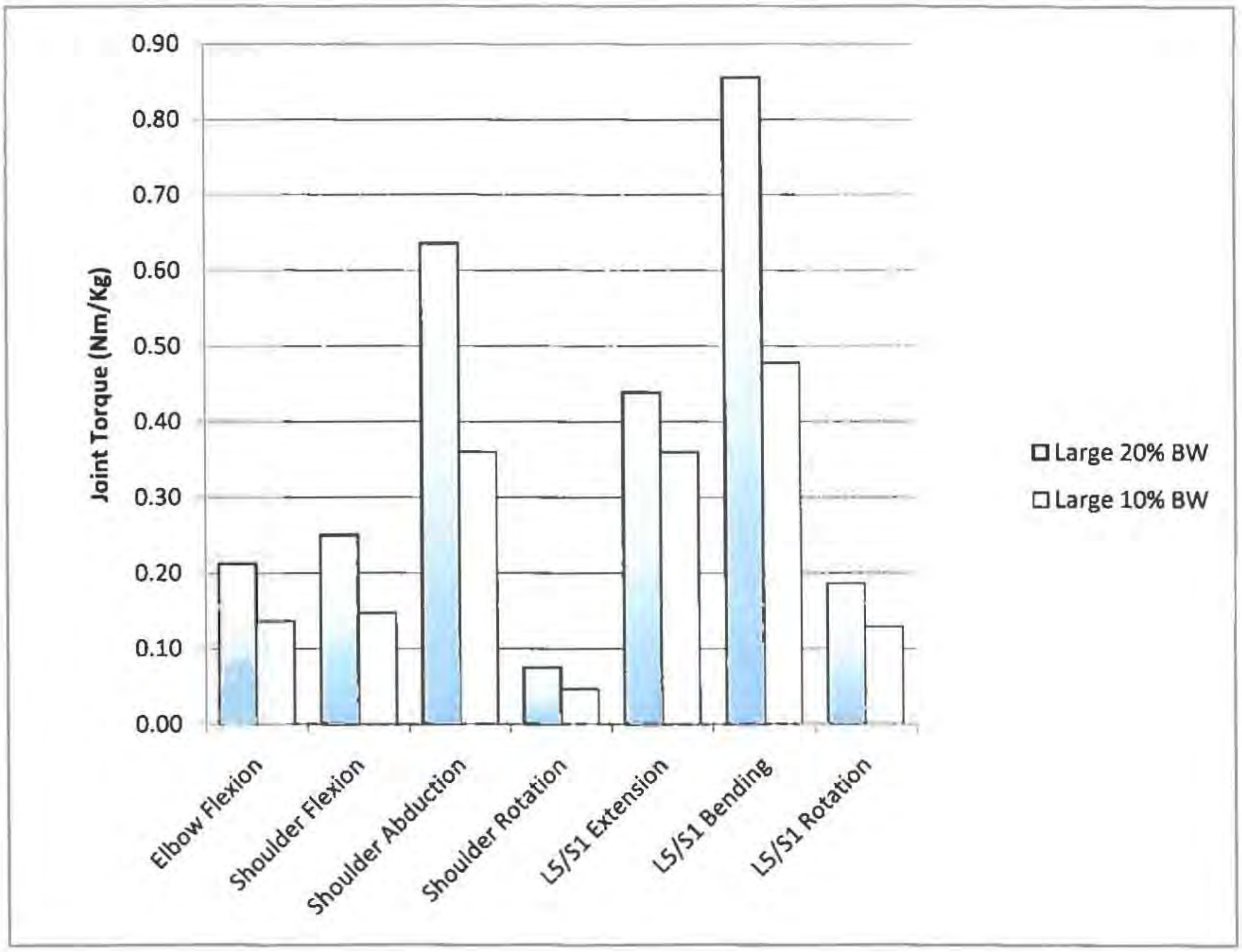

Figure 5. Maximum joint torques as a function of amount of unilateral large 20% BW bucket as compared to a unilateral large 10% BW bucket.

L5/S1 lateral bending ($p < 0.01$), and L5/S1 axial rotation ($p = 0.01$) torques were also significantly higher when carrying a unilateral small 20% BW bucket as compared to a unilateral small 10% BW bucket (Figure 6). Differences in maximum L5/S1 extension torques as a function of the amount of weight carried were not statistically significant ($p = 0.27$ and higher).

Effects of Loading Symmetry

Maximum elbow flexion ($p < 0.01$), shoulder flexion ($p < 0.01$), shoulder abduction ($p < 0.01$), shoulder external rotation ($p < 0.01$), L5/S1 lateral bending ($p < 0.01$), and L5/S1 axial rotation ($p < 0.01$) torques were significantly higher when carrying a unilateral small 20% BW bucket as compared to bilateral small 20% BW buckets (Figure 7). In addition, maximum shoulder abduction ($p < 0.01$), L5/S1 lateral bending ($p < 0.01$), and L5/S1 axial rotation ($p = 0.05$) torques were significantly higher when carrying a unilateral small 10% BW bucket as compared to bilateral small 10% BW buckets. However, differences in maximum elbow flexion, shoulder flexion, and shoulder external rotation due to unilateral versus bilateral carrying

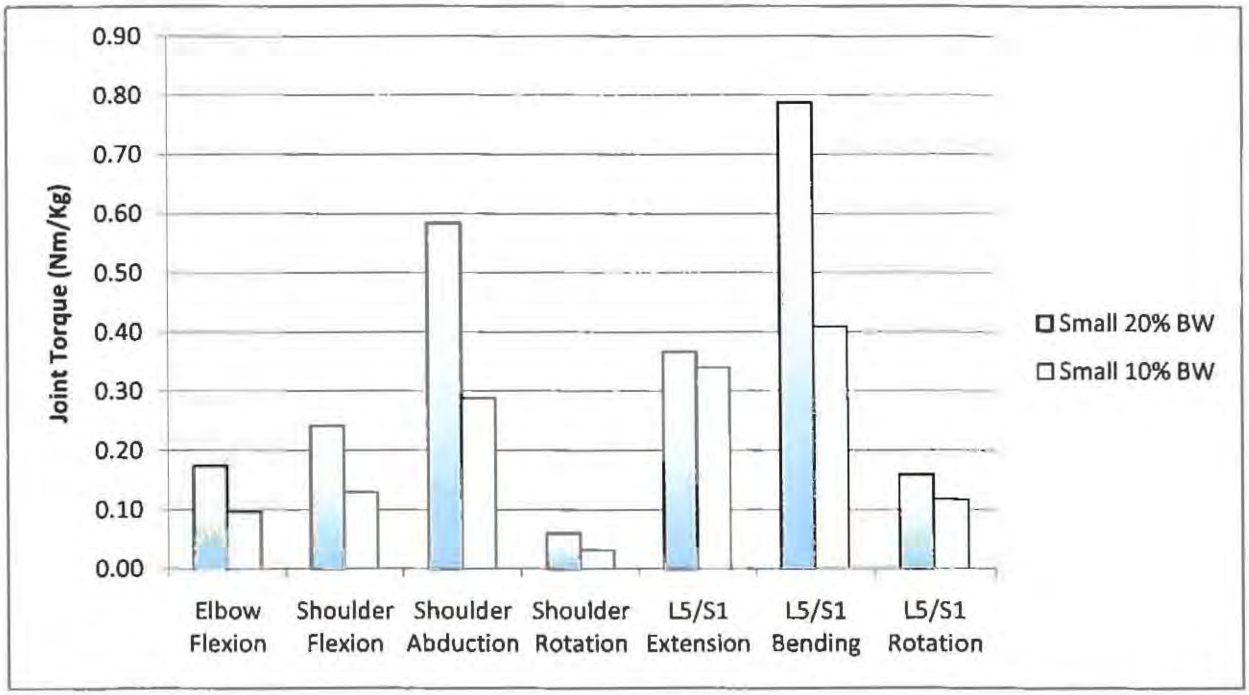

Figure 6. Maximum joint torques as a function of amount of unilateral small 20% BW bucket as compared to a unilateral small 10% BW bucket.

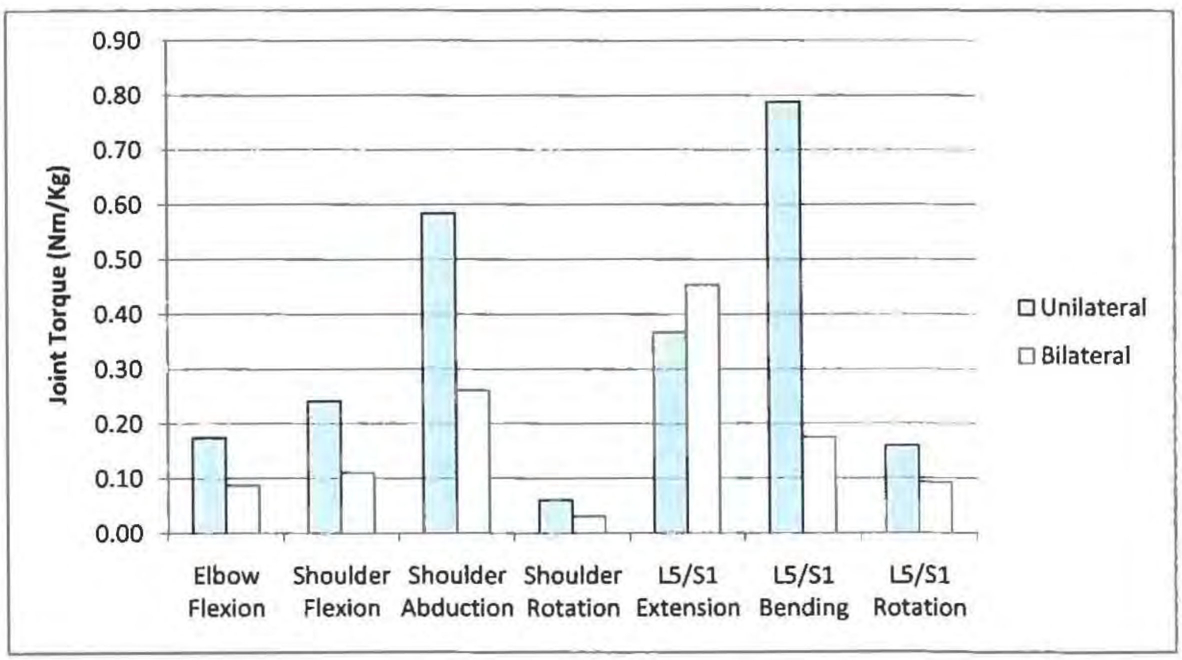

Figure 7. Maximum joint torques as a function of amount of unilateral small 20% BW bucket as compared to a bilateral small 20% BW bucket.

were not statistically significant with the 10% BW load ($p = 0.24$ and higher). Maximum L5/S1 extension torques were not dependent upon unilateral versus bilateral carrying at either the 10% or 20% BW load ($p = 0.09$ and higher).

Effects of Bucket Size

Maximum lateral bending torques were significantly greater when carrying the large bucket unilaterally as compared to carrying the small bucket unilaterally at both the 10% BW ($p = 0.04$) and 20% BW ($p = 0.04$) loads (Figure 8). Maximum elbow flexion, shoulder flexion, shoulder abduction, shoulder external rotation, L5/S1 extension and L5/S1 axial rotation torques were not were not dependent upon bucket size ($p = 0.12$ and higher).

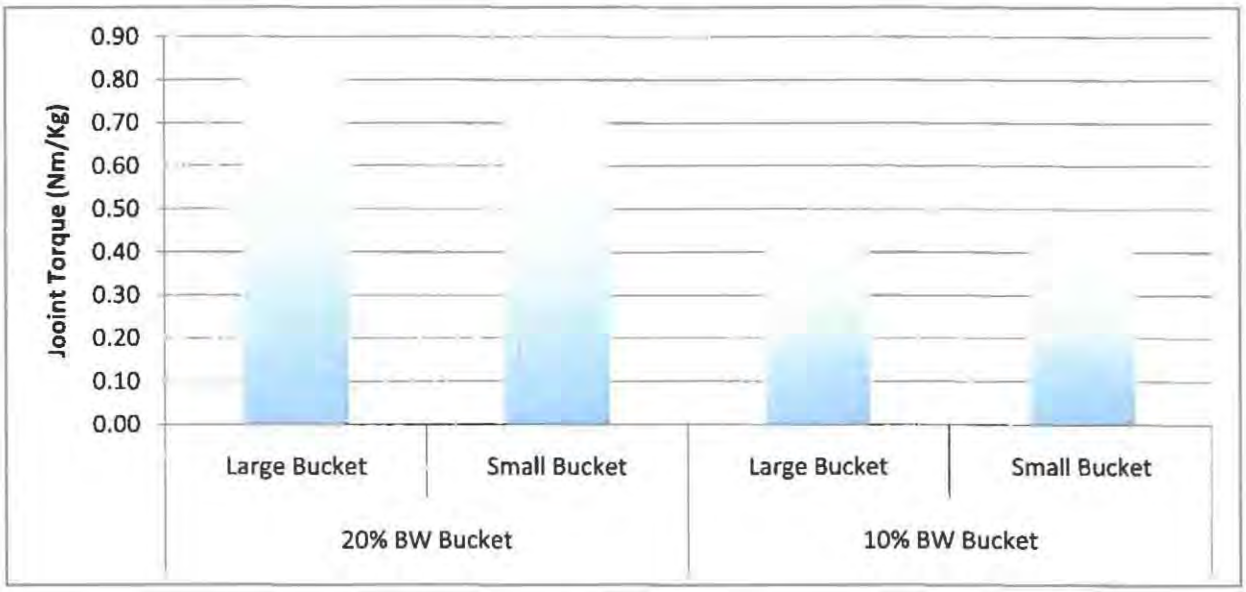

Figure 8. Maximum lateral bending torques as a function of amount of unilateral small 20% BW bucket as compared to a bilateral small 20% BW bucket.

Hypothesis Discussion

The first hypothesis was that maximum normalized shoulder abduction torques would be lower when carrying small (one-gallon) buckets as compared to large (five-gallon) buckets. This hypothesis was not supported since shoulder abduction torques were not significantly dependent upon bucket size (Figure 8). Although a larger bucket would move the center of the carried load further away from the body, the research participants could have adjusted their posture to avoid increased shoulder abduction torques. One way that this could be achieved is through increased lateral bending of the trunk, which would reduce the moment arm between the carried load and the shoulder joint. The fact that L5/S1 lateral bending torques were significantly higher when carrying the large bucket would appear to support this explanation.

The second hypothesis was that maximum normalized L5/S1 lateral bending torques would be lower when carrying the load bilaterally as compared to unilaterally. This hypothesis was supported since L5/S1 lateral bending torques were significantly higher with unilateral bucket carrying than with bilateral carrying (Figure 7). This is of interest since Seroussi and Pope (1987) found increased erector spinae electromyographic activity when testing frontal plane moments up to 26 Nm. In comparison, the maximum L5/S1 lateral bending moments averaged 22.7 Nm when carrying a unilateral 10% BW bucket and 43.7 Nm when carrying a unilateral 20% BW bucket in this study. Other studies have demonstrated spinal kinematic and kinetic differences with asymmetric loading at levels between 10% and 20% BW. Marras and Davis (1998) found increased spinal lateral shearing forces with one-handed lifting at an average of 17% BW, and Fowler et al. (2006) found increased lateral bending with asymmetric load carrying at 17.5% BW.

The third hypothesis was that maximum normalized shoulder abduction and L5/S1 lateral bending torques would be proportionally higher in the 8-10 year old group as compared to adults. This hypothesis was not supported and in fact, the opposite results were observed. Maximum shoulder abduction and L5/S1 lateral bending torques were significantly higher in adults than in 8-10 year olds (Figures 3 and 4). Higher shoulder abduction and L5/S1 lateral bending torques were predicted in 8-10 year olds on the premise that the loaded buckets would introduce a larger moment arm as a percentage of body size. While surprising initially, the results indicate that the 8-10 year olds were able to compensate for their smaller anthropometry through altered posture and technique.

While 8-10 year olds appeared to be able to compensate for unilateral lifting, it should be stressed that carried loads were set as a proportion of body weight. Therefore, 8-10 year olds were carrying an average of 52% absolute load that the adults were carrying. The amount of weight carried did have a distinct effect on the upper extremity and lower back torques. When increasing carried load from 10% to 20% BW, maximum normalized elbow flexion, shoulder flexion, shoulder abduction, shoulder external rotation, L5/S1 lateral bending, and L5/S1 axial rotation torques all significantly increased (Figure 5). The average amount carried in this study (54 N at 10% BW and 109 N at 20% BW) was comparable to loads measured in the field. Allread et al. (2004) reported the average load for carrying feed and water to be 83 N and estimated a 49% risk of lower back disorders. As a validation of this prediction model, Marras et al. (2000) found a significant correlation between reduction of lower back disorder risk rate and actual incidence rates. One limitation of this study is that a sample of convenience was used for research participants. Using the CDC growth charts, the participants in this study tended to be taller (+4% 8-10 years, ~0% 12-14 years, +5% 15-17 years) and heavier (+9% 8-10 years, +15% 12-14 years, +18% 15-17 years) than fiftieth percentile children (CDC, 2000). The three age groups of children did have distinct body sizes, as the average height and mass were separated from each other by over one standard deviation (Table 7). However, the 15-17 year olds had an average height and mass that was similar to adults. Differing rates of maturity for females and males may make it appropriate to set different age groupings by gender, but further studies with additional participants are needed before such divisions can be made. Another limitation of a controlled laboratory study is that a smooth, level walking surface and a solid carrying load was analyzed. For example, it is a reasonable assumption that balance would be more severely tested with rough outdoor terrain carrying buckets of water.

CONCLUSIONS

Several general conclusions may be drawn from this study. The higher loads carried (20% BW) in this study appear comparable to load levels associated with increased risk of lower back disorders found in previous studies. If it is practical in a field setting to carry lower amounts of weight (10% BW), then six of the seven maximum upper extremity/low back torques were significantly reduced. However, there was no evidence that carrying guidelines as a percentage of body weight should be lower for the 8-10 year old group. In addition, if it is feasible to split a load for bilateral carrying, then six of seven maximum joint torques were significantly reduced. However, modifying the carrying task by using smaller one-gallon buckets only produced significant reductions in maximum L5/S1 lateral bending torques.

Several initial carrying guidelines may be inferred from this study. First, the recommendation to scale the amount lifted to the individual's body weight is implicit in this study. At ten and twenty percent body weight, the 8-10 year olds did not have proportionally higher joint torques. Second, it is recommended that buckets be carried bilaterally when possible. Splitting a carried load between two buckets resulted in substantially lower shoulder abduction and L5/S1 lateral bending torques for all age groups. The advantages of using one-gallon instead of five-gallon buckets were not distinct.

In addition, future analyses may want to consider the effects of age and carrying condition on the loading of the lower extremities. While the youngest subjects appeared to hold their upper body rigid while carrying heavy buckets, an increase in out-of-plane motion of the lower extremities was observed.

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PUBLICATIONS

Journal Article

Gillette JC, Stevermer, CA, Meardon SA, Derrick TR, and Schwab CV: [2006] Upper Extremity and Lower Back Torques During Carrying Tasks in Farm Children. Journal of Applied Biomechanics In press

Proceedings

Gillette JC, Derrick TR, Schwab CV, Freeman SA, Stevermer CA, and Meardon SA: [2007] Evaluation of Occupational Carrying Tasks for Farm Youth. Paper No. 2007-03, Proceedings of the 2007 National Institute for Farm Safety International Meeting, Madison, WI 53706.

Conference Posters

Meardon SA., Gillette JC, Stevermer CA, Miller RH, Derrick TR, and Schwab CV: [2006] Age and Condition Related Differences During Carrying Tasks in Farm Youth. American College of Sports Medicine conference. Denver, CO.

Gillette JC, Stevermer CA, Meardon SA, Derrick TR, Schwab CV. [2006] Upper Extremity Torques During Carrying Tasks in Farm Children. American College of Sports Medicine conference. Denver, CO.

INCLUSION OF GENDER AND MINORITY STUDY SUBJECTS

The inclusion of gender and minority study subjects is provided in the PHS-2590 table on the following page (37).

INCLUSION OF CHILDREN

The target population for this study was children under the age of 18 in the rural Midwestern United States. This target population was sampled using children in rural Iowa. Subjects were recruited from local 4-H clubs and contacts with extension staff that interact with Iowa youth to match Iowa demographics. Four age groups of subjects were recruited; 8-10 years, 12-14 years, 15-17 years, and adult (over 18 years of age). The adult age group was a control group but by definition could contain children (18, 19, and 20 years of age). Children with specific medical conditions or recent surgeries that would impact the ability to conduct the trial were excluded from the study. This precaution was implemented to safe guard study participants.

MATERIALS AVAILABLE FOR OTHER INVESTIGATORS

The anthropometric data given in Tables 8 to15 is available for other investigators. It can be located in Scientific Report section.

Principal Investigator/Program Director (Last, First, Middle): Schwab, Charles, V.

Inclusion Enrollment Report

This report format should NOT be used for data collection from study participants.

Study Title: Evaluation of Occupational Carrying Tasks for Farm Youth

Total Enrollment: 88 **Protocol Number:**

Grant Number: RO1-OH008085-03

PART A. TOTAL ENROLLMENT REPORT: Number of Subjects Enrolled to Date (Cumulative) by Ethnicity and Race

	Sex/Gender			
Ethnic Category	**Females**	**Males**	**Unknown or Not Reported**	**Total**
Hispanic or Latino	0	1	0	1 **
Not Hispanic or Latino	4	9	0	13
Unknown (individuals not reporting ethnicity)	29	30	0	59
Ethnic Category: Total of All Subjects*	33	40	0	73 *
Racial Categories				
American Indian/Alaska Native	0	0	0	0
Asian	0	0	0	0
Native Hawaiian or Other Pacific Islander	0	0	0	0
Black or African American	1	1	0	2
White	32	39	0	71
More Than One Race	0	0	0	0
Unknown or Not Reported	0	0	0	0
Racial Categories: Total of All Subjects*	33	40	0	73 *

PART B. HISPANIC ENROLLMENT REPORT: Number of Hispanics or Latinos Enrolled to Date (Cumulative)

Racial Categories	**Females**	**Males**	**Unknown or Not Reported**	**Total**
American Indian or Alaska Native	0	0	0	0
Asian	0	0	0	0
Native Hawaiian or Other Pacific Islander	0	0	0	0
Black or African American	0	0	0	0
White	0	1	0	1
More Than One Race	0	0	0	0
Unknown or Not Reported	0	0	0	0
Racial Categories: Total of Hispanics or Latinos**	0	1	0	1 **

* These totals must agree.
** These totals must agree.