CHILDREN’S POSTURES WHILE PLAYING AT COMPUTER WORKSTATIONS

by

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Abstract

There has been a significant increase in the incidence of musculoskeletal disorders (MSD) and the costs associated with these are predicted to increase as the popularity of computer use increases at home, school and work. Risk factors have been identified in the adult population but little is known about the risk factors for children and youth. Research has demonstrated that they are not immune to this risk and that they are self reporting the same pain as adults. The purpose of the study was to examine children’s postures while working at computer workstations under two conditions. One was at an ergonomically adjusted children’s workstation while the second was at an average adult workstation. A Polhemus Fastrak™ system was used to record the children’s postures and joint and segment angles were quantified. Results of the study showed that children reported more discomfort and effort at the adult workstation. Segment and joint angles showed significant differences through the upper limb at the adult workstation. Of significance was the strategy of shoulder abduction and flexion that the children used in order to place their hand on the mouse. Ulnar deviation was also greater at the adult workstation as was neck extension. All of these factors have been identified in the literature as increasing the risk for injury. A comparison of the children’s posture while playing at the children’s workstation verses the adult workstation, showed that the postural angles assumed by the children at an adult workstation exceeded the Occupational Safety and Health Association (OSHA) recommendations. Further investigation is needed to increase our knowledge of MSD in children as their potential for long term damage has yet to be determined.
Acknowledgements

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Statement of Originality

I hereby certify that all of the work described within this thesis is the original work of the author. Any published (or unpublished) ideas and/or techniques from the work of others are fully acknowledged in accordance with the standard referencing practices.

Carol Anne Murphy

May, 2011
# Table of Contents

List of Figures ........................................................................................................................................ix  
List of Tables .........................................................................................................................................xi

CHAPTER 1 INTRODUCTION ............................................................................................................... 1

CHAPTER 2 LITERATURE REVIEW .................................................................................................... 4

2.1 An Approach to the Problem ........................................................................................................ 4

2.2 Adult MSD Definition and Etiology ............................................................................................ 9

2.2.1 Adult Risk Factors .................................................................................................................. 10

2.2.2 Prevalence and Type of Injuries in Adults ........................................................................... 12

2.2.3 Health Costs Associated with MSD .................................................................................... 13

2.3 MSD Prevalence in Children and Youth Populations ................................................................. 14

2.3.1 Computer Use by Children and Youth ............................................................................. 16

2.3.2 Children’s Risk Factors ....................................................................................................... 17

2.3.3 Childhood LBP Link with Computer Use ........................................................................... 18

2.4 Intervention verses Prevention .................................................................................................. 19

2.5 Anatomical and Developmental Factors .................................................................................... 20

2.5.1 Skeletal Structure ................................................................................................................ 21

2.5.2 Growth Patterns .................................................................................................................. 22

2.5.3 Spinal Curves ....................................................................................................................... 23

2.5.4 Clinical Postures .................................................................................................................. 25

2.5.5 Muscular Developments ....................................................................................................... 27

2.6 External Risk Factors ...................................................................................................................... 29

2.6.1 Computer Vision Syndrome ................................................................................................. 29

2.6.2 Visual Display Terminals ...................................................................................................... 32

2.6.3 Wrist Posture ....................................................................................................................... 33

2.6.4 Mouse Placement .................................................................................................................. 34

2.6.5 Keyboard Placement ............................................................................................................. 36

2.6.6 Forearm Posture .................................................................................................................... 36
2.6.7 School Furniture and Anthropometrics ................................................................. 37
2.6.8 Sitting Postures .................................................................................................. 40
2.7 Other Factors ........................................................................................................ 43
  2.7.1 Obesity as a Risk Factor ................................................................................. 43
  2.7.2 Television Watching ....................................................................................... 44
  2.7.3 Psychosocial Considerations ........................................................................ 45
  2.7.4 Low Back Pain and Computer Use ................................................................. 46
  2.7.5 Headaches and Upper Back and Neck Pain .................................................. 48
  2.7.6 School Performance ...................................................................................... 49
  2.7.7 Parental Issues .............................................................................................. 50
2.8 Summary ............................................................................................................... 51
CHAPTER 3 METHODS ................................................................................................ 52
  3.1 Design of the Study ............................................................................................ 52
  3.2 Participants ......................................................................................................... 52
  3.3 Work Station Set-up and Instrumentation ......................................................... 53
  3.4 Testing Protocol ................................................................................................ 60
  3.5 Procedures .......................................................................................................... 61
  3.6 Data Processing and Analysis of Objective Measures ....................................... 63
  3.7 Data Analyses and Processing of Subjective Measures .................................... 66
CHAPTER 4 RESULTS AND DISCUSSION .................................................................. 67
  4.1 Segment Angle Analysis .................................................................................... 68
    4.1.1 Hand Segment Angles ................................................................................. 68
    4.1.2 Forearm Segment Angles ......................................................................... 70
    4.1.3 Arm Segment Angles ............................................................................... 72
  4.2 Relative Angle Analysis .................................................................................... 73
    4.2.1 Wrist Joint Angles .................................................................................... 73
    4.2.2 Elbow Joint Angles .................................................................................. 76
    4.2.3 Shoulder Joint Angles .............................................................................. 76
  4.3 Spinal Joint Angles ............................................................................................ 79
    4.3.1 Spinal Lateral Bending Joint Angles ......................................................... 79
    4.3.2 Spinal Flexion/Extension Joint Angles ...................................................... 81
    4.3.3 Spinal Rotation Joint Angles .................................................................... 83
4.4 Subjective Data Results ........................................................................................................ 84
  4.4.1 National Longitudinal Survey of Children and Youth ............................................. 84
  4.4.2 Visual Analogue Scale (VAS) ............................................................................... 86
  4.4.3 Children’s Rate of Perceived Exertion (PCert) ...................................................... 87

CHAPTER 5 GENERAL DISCUSSION ...................................................................................... 88

CHAPTER 6 CONCLUSIONS, LIMITATIONS AND FUTURE DIRECTIONS ....................... 98
  6.1 Conclusion ..................................................................................................................... 98
  6.2 Limitations ..................................................................................................................... 98
  6.3 Future Directions ......................................................................................................... 100

REFERENCES ............................................................................................................................ 103

Appendix A Ethics Approval ................................................................................................ 123
Appendix B Letter of Information and Consent .............................................................. 124
Appendix C National Longitudinal Survey of Children and Youth 2002/03 ............ 128
Appendix D Anthropometric Measures ........................................................................ 129
Appendix E Summary of Anthropometric Measurements of Participants ............... 130
Appendix F Pilot Study ......................................................................................................... 131
Appendix G Visual Analog Scale (VAS) ........................................................................ 132
Appendix H PCert Scale ..................................................................................................... 133
Appendix I VAS and PCert Results ................................................................................ 134
Appendix J OSHA Guidelines vs. AAW and CAW Results ........................................... 135
List of Figures

1. Two Global® chairs were used with the child version customized for 8 and 9 year old anthropometrics. ............................................................................................................................ 55
2. Comparison of the CAW and AAW setups. ........................................................................... 56
3: Reference chart for joint and segment angles ............................................................................. 58
4 Difference between AAW and CAW setup. .................................................................................. 59
5. Recording setup up and sample of a participants AAW wrist data collection.................. 60
6. Sensor placement. ................................................................................................................... 61
7. A comparison of a 100 point sample (red) vs. a 2400 point sample (blue). Note that the red vertical lines have been added for easier viewing ................................................................. 64
8. The extension segment angle of the hand was significant (p=0.01) at the AAW............... 69
9. Forearm segment angles were significantly greater in all angles for the AAW. ................. 71
10. Arm segment angles were significantly greater in all mean angles for the AAW............... 73
11. The wrist showed more extension at the CAW than at the AAW and more ulnar deviation at the AAW. ....................................................................................................................................... 74
12. Strategies used to keep the wrist straight at the adult-adjusted workstation by: A) resting the forearm on the table or B) bringing the mouse closer to the edge of the table. ....................... 75
13. Ulnar deviation of the wrist was (A) minimal in a CAW but (B) could be exaggerated in some children in the AAW. ........................................................................................................... 76
14. There were significant differences in shoulder joint abduction and flexion between the AAW and CAW............................................................................................................................ 77
15. At the AAW, children either (A) kept their shoulder close to their body or (B) abducted their shoulder and rested their elbow on the desk ........................................................................ 78
16. A comparison of one child’s shoulder flexion angles between an (A) AAW ........................... 79
17. Spinal lateral bending, while not significant, was greater in the thoracic spine at the AAW due to the postural adaptation of the shoulder. ................................................................. 80
18. Neck extension was greater in the AAW while there was greater thoracic flexion at the CAW, although both were not significant. ................................................................. 82
19. Rotation angles were not significant throughout the spinal curves. There was more movement at the neck joints than in the thoracic and lumbar areas across conditions .......... 83
20. A summary graphic of the mean pain scores on a VAS scale before and after each condition. ........................................................................................................................................................................... 86

21. A comparison of mean PCert scores after 20 minutes of computing on AAW vs. CAW .... 87
List of Tables

1. Frequency Analysis of National Longitudinal Survey of Children and Youth .................. 85
2. Summary of Anthropometric Measurements of Participants ............................................. 130
3. Results of VAS survey ........................................................................................................ 134
4. Results of PCert Survey ...................................................................................................... 134
5. OSHA Guidelines vs. AAW and CAW Results ................................................................. 135
### Glossary of Abbreviated Terms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>AAW</td>
<td>Adult Adjusted Workstation</td>
</tr>
<tr>
<td>AHKC</td>
<td>Active Healthy Kids Canada</td>
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<tr>
<td>BMI</td>
<td>Body Mass Index</td>
</tr>
<tr>
<td>CAW</td>
<td>Child Adjusted Workstation</td>
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<td>CCHS</td>
<td>Canadian Community Health Survey</td>
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<tr>
<td>CTS</td>
<td>Carpal Tunnel Syndrome</td>
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<td>CVD</td>
<td>Cardiovascular Disease</td>
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<td>CVS</td>
<td>Computer Vision Syndrome</td>
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<td>EMG</td>
<td>Electromyography</td>
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<td>IBM</td>
<td>International Business Machine</td>
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<td>IWH</td>
<td>Institute of Work and Health</td>
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<td>LBP</td>
<td>Low Back Pain</td>
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<td>MSD</td>
<td>Musculoskeletal Disorders</td>
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<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
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<td>MUs</td>
<td>Motor Units</td>
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<tr>
<td>NLSCY</td>
<td>National Longitudinal Survey of Children and Youth 2002/03 (Adapted)</td>
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<tr>
<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
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<tr>
<td>PCert</td>
<td>Perceived Child Rate of Exertion</td>
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<tr>
<td>RMS</td>
<td>Room Mean Square</td>
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<td>SD</td>
<td>Standard Deviation</td>
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<td>sEMG</td>
<td>Surface Electromyography</td>
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<tr>
<td>SEM</td>
<td>Standard Error of the Mean</td>
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<td>VAS</td>
<td>Visual Analogue Scale</td>
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<td>VDT</td>
<td>Visual Display Terminal</td>
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CHAPTER 1
INTRODUCTION

The expressions “tip of the iceberg” and “epidemic” commonly appear in the literature and popular media to describe the increasing prevalence of musculoskeletal disorders (MSD) and repetitive stress disorders in adults. This increase has been associated with several factors including: increasing use of computers at work, school and home, declining fitness levels, increasing obesity rates, as well as other related factors such as stress, occupational factors, and environmental factors (Berner & Jacobs, 2002; Gerr, Marcus, & Monteilh, 2004; Janssen, 2007; Tittiranonda, Burastero, & Rempel, 1999). There has been increasing concern that children are not immune to this risk. Recent studies have shown that children and adolescents are reporting musculoskeletal pain with the same frequency as adults (Jacobs & Baker, 2002). There are several longitudinal studies that show child and adolescent musculoskeletal health issues persist to become adult musculoskeletal health issues and that onset as a child is a predictor of future health issues (Knusel & Jelk, 1994; Smith et al., 2003).

Children have been identified as ‘at risk’ due to a variety of factors including increasing use of computers in all aspects of their lives combined with immature and developing musculoskeletal systems. Parents comment that computers are being increasingly used as a means of communication among children and youth and computers are now replacing television for watching television shows and movies as well as playing
video games. Schools are also increasing the use of computers in all aspects of education. At one time, they were seen as an adolescent educational tool but now they have become part of everyday student life starting in junior kindergarten (Kimmerly & Odell, 2009). Computer games for young children abound, both educational and recreational, and children are starting to use computers at home at a very early age (Blackstone et al., 2008). Future changes will undoubtedly increase the time children spend on computers. The computer as part of our children’s lives is here to stay. It will undoubtedly take new forms as advancements in technology are made; however, for this current generation, keyboarding and using a mouse on a laptop, tablet or desktop are a reality.

The actual postures that children assume when they are working at computer workstations have not been well documented. Gillespie (2002) reported that children using computer and electronic games adopt sustained and awkward postures that are associated with MSD in working adults. These postures increase the risk further if they are sustained while children are working at computer workstations designed for adult anthropometrics. This anthropometric mismatch makes the adult workstation ergonomically deficient for children. In a study of 152 grade six children where computer set-up and home use were examined, more than one half reported some MSD in the past year and that it was made worse by computer use. There was also a significant association between the numbers of hours on the computer and overall musculoskeletal
discomfort. Finally, results indicated that those students without proper furniture were more likely to have musculoskeletal discomfort (Jacobs & Baker, 2002).

While the Gillespie (2002) study offered a qualitative approach to MSD and postures, the use of quantitative data combined with a qualitative approach has been underutilized. The purpose of this study was to examine children’s posture while working at: a) an adult workstation with an adult keyboard, mouse and monitor; and, b) a child’s ergonomically adjusted workstation with a child’s size keyboard, mouse and monitor. Postures were quantified by determining the joint and segment angles and linear displacements of key anatomical areas through the use of a three dimensional measurement system. It was hypothesized that children’s postures when working at an adult’s workstation would not follow guidelines for computer workstations established by Occupational Safety and Health Administration (OSHA), while postures working at the children’s workstation would meet these guidelines. A secondary purpose was to determine if the children subjectively reported greater discomfort at either workstation. It was hypothesized that children would report greater discomfort while working at an adult workstation.
CHAPTER 2
LITERATURE REVIEW

2.1 An Approach to the Problem

Specific musculoskeletal disease conditions and syndromes are well documented and researched; however, the area of MSD has not been investigated to the same extent. There has been extensive research on sports injuries, fractures, sprains, strains, tears, ruptures, avulsions, bursitis, tendonitis, and others; all of which are traumatic in origin. Research has traditionally focused on acute onset injuries, which produce demonstrable objective results and which can be measured and assessed, using a spectrum of clinical skills and tools ranging from orthopaedic examination to MRI. The non specific, insidious, chronic and episodic musculoskeletal conditions have not enjoyed the same level of interest. This is especially true of the child and youth population.

Children are seen as inherently resilient in their ‘bump and fall’ years. Unless there is trauma, children traditionally have been left to recover on their own. Symptomatic management ranging from pharmaceutical to bracing may be recommended when required for pain relief and function. However, a new generation of musculoskeletal conditions has developed as a result of changes in our technology, workplace and social media. The results of these changes have been well documented in the adult population and the red flag of concern has been raised. The economic costs of this particular group of conditions and injuries carry with it a substantial burden both in terms of treatment and management but also, and more importantly, long term disability.
This red flag is now being raised in the child and youth population. Children and youth, long thought to be “quick healers”, are now presenting with chronic overuse injuries more typical of their parents. That is why it is alarming to see recent studies in the literature identifying children as an ‘at risk’ population for MSD (Burke & Peper, 2002; Harris & Straker, 2002). This is in stark contrast to 1987 when carpal tunnel syndrome was identified as extremely rare in childhood and, in almost all previously reported cases, it had been secondary to some underlying condition (Sainio, Merikanto, & Larsen, 1987).

The research community needs to further the body of knowledge on children and youth and MSD. Research in the adult population has demonstrated that certain factors can be identified as “causal” or contributory to these injuries and this has resulted in a number of recommendations, treatment and management options for adults with these conditions, albeit with varying levels of success. In children, however, this is a relatively new area of research. We have yet to investigate several key concepts. Does the fact that children have musculoskeletal systems that are developing affect their injury and recovery rate? Are the mechanisms of injury the same as in adults? What risk factors are important for this population and are they the same risk factors as for the adult population? Harris & Straker (2000) note that due to the nature of children and their environment, the risk factors and their causal relationship would vary from the adult model. Are the solutions the same as for the adult populations? The questions to be answered are many so it is important to identify where to begin this research.
Computer use has been identified as one of the risk factors for this spectrum of conditions (USDHHS, 1997). What is integral in children using computers that causes them to develop these conditions? In examining all of the issues and reviewing the literature, it is apparent that an appropriate starting point should be the risk factors in a computer workstation that need to be identified as they relate specifically to a child population. What specific areas of concern could; 1) be identified in this specific population, 2) be related to computer use, and 3) have the potential to contribute to MSD?

The next question is how to quantify these areas of concern. Do the risk factors manifest or reveal themselves in a way that is identifiable and quantifiable? What are children doing at computer workstations that could put them at risk for injury? Upon review it has been determined that the common denominator for all of the risk factors is the posture that the children assume while working or playing at a computer workstation.

Posture is the method by which children accommodate and adapt to the limitations of their environment. Ultimately they will perform the task required and they will make the necessary adaptations to allow this to occur. If the task is important, it has been documented that children will continue working despite discomfort (Harris & Straker, 2000). How they make these adaptations is the starting point of research into children and MSD. What postures are children actually using to accomplish the tasks before them? Are these individual adaptations or can we discover common patterns of postural accommodations?
The next question then becomes; how can we affect these postural adaptations? If we have identified a risk factor, we are hopefully able to identify a correction, alternative or solution. In this case, if postural adaptations are in themselves the risk factor, how do we minimize their affect? However, first we need to understand why they are making the adaptations. If we can understand the children’s reasons for their postural corrections, we can look for ways to create an environment where correction is not required. How does changing their posture improve their ability to perform the task and why is it instinctive for them to make this correction? Some may consider the answer intuitive. Children are making postural adaptations to allow them to work at workstations which do not match their anthropometric requirements. They are working at home on adult workstations and at school on computer workstations that are not adjustable. Children are using their posture to adapt themselves to their workstation which would then allow them to complete their tasks, whether it be play a game or complete a school assignment.

Based on Gillespie’s (2002) work and a distillation of important questions, it was felt that the starting point for this research needed to be an understanding of children’s postures at computer workstations. What are the children doing and what postures are they assuming to complete their tasks? Correcting their strategies or developing an intervention-based program will not be helpful as these changes may simply prevent them from completing their tasks. Prevention needs to be the primary objective. There should be no need for corrections. Children should be able to work at a computer workstation with proper posture as defined by occupational health and safety guidelines. Children
should be able to complete their tasks without adapting their posture to their workstation. How can this be achieved? In order to eliminate the need for postural corrections, an ergonomically correct workstation needs to be used. If this is a solution, it would be anticipated that children should demonstrate different postures performing a task at a standard adult workstation versus an ergonomically correctly adjusted child workstation.

The question of which postures to measure and how to measure them is the next issue. Postures to be measured are identified as those that are in accordance with the recommendations by OSHA for computer workstations (Table 5). A three dimensional measuring system that allows measurements to be taken and analyzed would allow us to quantify these postures. This approach will answer the identified purposes and provide a baseline of information on what postures children are actually using while playing on a computer and if those postures can be affected by computer workstation design.

A literature review is provided of those factors that are considered relevant to computer use as it applies to children and youth. The literature review has been organized under the following sections. The first section covers the status of adult MSD including; definition and etiology, risk factors, prevalence of computer use, and health care costs attributable to computer use. The second section deals with the status of MSD among children including; prevalence, computer use, risk factors, intervention versus prevention, musculoskeletal predisposition and developmental considerations, computer workstation design factors and other related factors. As discussed, research studies
specific to children are limited; however, we can also learn about potential future risks for children from adult studies as well as the actual risks that children experience.

2.2 Adult MSD Definition and Etiology

In the scientific literature, occupational injuries associated with computer use started appearing with increasing frequency over the past three decades. A number of terms have been used to describe the same complex of symptoms, namely: musculoskeletal disorders (MSD), cumulative stress disorders (CSD) and repetitive stress injuries (RSI). For the purpose of this thesis, the term MSD will be used.

The increase in MSD has been associated with the increasing use of computers. In 1981 when the IBM personal computer was first introduced, the incidence of MSD was reported as 18%. This rate of MSD has increased with the growing use and popularity of computers to 28% in 1984, 52% in 1992 and 70% in 2000. This trend is only expected to continue as society evolves to use computers in a primary function both at home and at work. The nature of the workplace continues such that computer use is becoming a requirement in an increasing variety of occupations and its use is unlikely to decrease.

It is important to understand that MSD develop gradually and are not the result of a single event, accident or injury. Normally, excessive stretching of muscles and tendons can cause pain that disappears after several days; however, with MSD, it is the repeated stretching and use that damages the soft tissues, causing inflammation and eventually long-lasting injury to muscles, tendons and nerves. MSD usually affect the hands, wrists,
elbows, neck and shoulders but can also occur in the legs, hips, ankles and feet. Back problems are usually not included when measuring MSD but are considered a separate condition. MSD can be categorized as non-specific and include symptoms such as generalized pain, swelling, weakness or discomfort or they can be specific disorders like tennis elbow or carpal tunnel syndrome (Institute of Work and Health (IWH), 2005).

Research has shown that frequent and repetitive activities and those that involve forceful movements or prolonged or awkward postures increase the risk of MSD. Movements such as bending, straightening, gripping, holding, twisting, clenching and reaching are not usually harmful; however, when they are performed over and over again and there is insufficient recovery time between work periods, they can cause injury (IWH, 2005).

2.2.1 Adult Risk Factors

MSD are best thought of as cumulative disorders wherein risk factors have been identified as causal or associated conditions. These risk factors have been thought to predispose or contribute to this cumulative effect. Much research has been done to determine the risk factors and causal relationships associated with MSD (Falkiner & Myers, 2002; Gillespie, 2002). The links are not clearly defined but Falkiner and Myers (2002) felt that computer work acts like a ‘last straw’ in causation in people who have other causal factors as well. Risk factors from the literature have been classified into different areas; individual factors (e.g. genetics, age, gender, anthropometry, psychosocial profile, cognitive, physiology), physical environment (e.g., heat, humidity,
lighting) and biomechanical factors (e.g. force, posture, movement and vibration) and task demands/work organization (e.g. repetitive paced tasks) (Harris & Straker, 2000; Cote et al., 2008).

The IWH has identified physical risk factors to include uncomfortable workstations that result in poor posture, awkward postures for extensive periods of time and repetitive loading or lifting (IWH, 2005). Studies have identified specific ergonomic variables as risk factors in computer use; static work posture, hand position, use of lower arm support, repeated work movements and keyboard or the vertical position of visual displays (Bergqvist, Wolgast, Nilsson, & Voss, 1995). Specific postures have also been identified as increasing risk, especially the non neutral joint posture that has been shown to be associated with development of upper extremity conditions (Blackstone & Johnson, 2006; Gerr et al., 2004). This non neutral posture is unfortunately a common strategy or habit of computer users as shown in a study where 61% of computer operators were observed in non neutral shoulder postures and 41% in non neutral wrist postures (Gerr et al., 2000). Organizational factors were also identified as risk factors and included: a lack of participation in decisions about how work is designed, monotonous work, high work intensity, low job control, unclear job roles and poor workplace social support (IWH, 2005).
2.2.2 Prevalence and Type of Injuries in Adults

The increase in computer use has been associated with an increased prevalence of disorders in the neck and upper extremities. Poor workstation design has been associated with an increased risk of developing these symptoms. A survey study was done with 56 workplaces and 783 employees in which musculoskeletal pain was common among computer workers in offices. The 12 month prevalence was reported as: neck 63%, shoulders 24%, elbows 18%, lower arms and wrists 35%, and fingers 16%. There was, however, no association between the duration of computer work and pain, or between the duration of the mouse use and pain. Workers’ perception of their workstations as being poor ergonomically was strongly associated with an increased prevalence of pain (Sillanpaa et al., 2003).

In a prospective study of computer workers, 632 newly hired workers were followed for up to three years. They found that of new workers, 50% reported musculoskeletal symptoms after only one year of employment and further, that hand and arm, neck and shoulder symptoms and MSD were common among computer users (Gerr et al., 2002).

In a study of 515 office workers, 34.4% reported neck pain for at least eight days during the past 12 months. Poor physical work environment and poor placement of the keyboard increased the risk of neck pain. Female sex was also a predictor as were smoking, mental stress and lack of physical exercise (Korhonen et al., 2003).
A survey of 149 computer operators found that MSD were more prevalent when using a mouse for the arm and hand as well as for women more so than men. They cited repetitive movements, static postures (ulnar deviation and extended wrist) and static muscular activation patterns as risk factors (Jensen et al., 1998).

Prevalence of MSD has also been demonstrated in the statistics associated with disability and compensation costs. Data show that up to 70% of claims to Ontario’s Workplace Safety and Insurance Board (WSIB) are related to MSD (including back) and that more than 50% are due to non-traumatic causes such as carpal tunnel syndrome (CTS) or tendonitis (IWH, 2005).

2.2.3 Health Costs Associated with MSD

In 1995, a Health Canada report calculated that the annual cost of MSD to Canadian society was around $17.8 billion. This was second only to cardiovascular disease which cost $19.7 billion. This was updated in 1998 in a report called The Economic Burden of Illness in Canada. They reported that the indirect costs were highest for MSD, and then cancer and cardiovascular disease (CVD). They also noted that, while the indirect costs for cancer and CVD are related mainly to mortality, costs associated with MSD were overwhelmingly due to long-term disability (IWH, 2005).

The Occupational Safety and Health Association in the U.S. shows MSD as the fastest growing category of illness and the fastest growing cause for disability in the United States according to the Bureau of Labor Statistics. In 1999, over one million persons were disabled due to musculoskeletal disorders and the United States government
and Social Security participants paid out over nine billion dollars in benefits for this category of illness (Hainsworth, 2002).

The costs associated with MSD are enormous, both in terms of the direct health care costs of simply treating the physical condition itself and the indirect health care costs such as mental and emotional stress and their long term health implications. There are also the costs to society for short or long term disability, not to mention the costs to industry, business and the economy from lost wages, time off work, replacement staff, retraining, and productivity and compensation payments (Hainsworth, 2002).

Direct medical costs in the United States exceed $1 billion per year with over 200,000 surgical procedures performed annually for carpal tunnel syndrome. Millions of dollars are also spent on ergonomic aides, many of which are as yet unproven. A survey of 30,000 workers affected by CTS reported that they lost a median of 25 works days and the incidence was estimated at 0.1 % to 10% (Patterson & Simmons, 2002). The median days off work are the highest for CTS at 27 days verses 20 for fractures and 18 for amputations (Falkiner et al., 2002).

2.3 MSD Prevalence in Children and Youth Populations

Statistics involving children, teenagers and young adults and MSD are of considerable concern. According to the Bureau of Labor Statistics, in 1999 there were 52,000 teenagers and young adults under the age of 30 who were on Social Security Disability due to musculoskeletal disorders. In addition, of the 582,000 employees in 1999 who missed time away from work due to these disorders, 72,000 or 12% were under
the age of twenty-four. These disorders include sprains, strains, carpal tunnel, tendonitis, soreness, pain and back pain (Hainsworth, 2002).

Prevalence has also been demonstrated in the non-employed portion of this age group. In a study of university students, over fifty percent of undergraduate students reported having pain and discomfort while working at the computer and 12.5% reported problems after only one hour or less at their workstation (Katz et al., 2000).

Results of a questionnaire based survey of 212 students, grades 1-12 concluded the following: many students had increased physical discomfort related to computer use, wrist pain (30%) and back pain (15%). Certain computer activities were predictive of physical discomfort including using a joystick and playing non educational games. Many parents reported difficulty getting their children off their computer (45%) and 35% reported their children spend less time outdoors. The authors concluded that computer use in children and adolescents was associated with self-reported physical discomfort (Burke & Peper, 2002).

Jacobs (2002) examined 321 students in grades six and seven and found that 42% reported experiencing computer related MSD after working on a computer. Jacobs also found that the relationship between the frequency of symptoms and reported number of hours per day was not significant. Of those reporting pain, 40% reported taking a break at least once an hour. Students who reported pain also reported more difficulty performing various functional activities such as carrying books and playing games.
2.3.1 Computer Use by Children and Youth

Data from the Active Healthy Kids Canada (AHKC) Report Card (2011) notes that Canadian children and youth rank among the highest in the world for computer use and that their usage has increased dramatically over the past several years. The Health Behaviour in School-Aged Children Survey 2005-2006, report that, on average, Canadian youth are accumulating the equivalent of a full time job per week averaging 6 hours of screen time on weekdays and more than 7 hours on weekend days (AHKC, 2008; AHKC, 2009). This has been facilitated by our higher socioeconomic status which enables access to home, school and work computers. Statistics Canada 2009 reports that 81.7 % of homes reported owning a computer and 77.8 % of homes have access to internet (AHKC, 2010). A typical home for an 8 to 18 year old now contains an average of 3.8 TVs, 2.8 DVD or VCR players, one digital video recorder, 2.2 CD players, 2.5 radios, 2 computers and 2.3 console video game players (Rideout, Foehr, & Roberts, 2010).

This trend is supported by increases in home Internet access which in the past 5 years has expanded from 74% to 84%. The proportion of 8- to 18-year-olds with a laptop has grown from 12% to 29%, and Internet access in the bedroom has gone from 20% to 33% (Rideout et al., 2010).

This access, frequency and lifestyle of constant screen time is complicated by the fact that less than half of the children are physically active enough on a daily basis to meet the requirements for healthy growth and development. Overall, according to the Canadian Health Measures Survey, only 9% of boys and 4% of girls meet the new
Canadian Physical Activity Guidelines, which state that at least 60 minutes of moderate- to vigorous-intensity physical activity should be accumulated daily (AHKC, 2011). This lack of musculoskeletal activity and fitness in children, which is particularly important during their critical growth, development and consolidation years, may contribute to risk factors for the musculoskeletal system in that is inherently compromised due to this lack of physical activity.

This trend of computer use, at the expense of physical activity, has been escalating and shows no sign of reversal. The Kaiser Foundation Report suggests that TV as a medium is decreasing in usage as other media (e.g., iPods, hand-held devices, laptops) alter the way children and youth watch TV shows and movies (Rideout et al., 2010).

All of these trends have resulted in Canada receiving a failing grade of F on the Active Healthy Kids Report Card for 2009, 2010 and 2011. This declining trend is in contrast to 2005 when Canada received a C and 2006 through to 2008 when they received a D (AKHC, 2009). Canada is not alone in this trend. Christakis et al. (2004) in a telephone survey of 1454 parents of children < 11 years old (average of 5.05 years) from a diverse population in the U.S. found that combined video and computer game usage exceeded television usage.

2.3.2 Children’s Risk Factors

Children have not been shown to be immune to the same risk factors that adults are exposed to and have become victims as well. Harris et al. (2005) notes that as
children use computers as part of their normal daily life in education, leisure and communication, at both school and home, they may be at greater risk for the development of MSD. An additional concern is that children are often involved in other similar tasks such as playing a musical instrument out of school hours which further increases their risk. This is compounded by the portability of computers that allow them to be used anywhere.

A 1998 survey in Japan of elementary, junior high and high schools found that most schools have been slow to develop instructive programs from the environmental or ergonomic point of view and they concluded that an effective way to prevent problems is to educate the students with the knowledge to protect themselves. They further note that there is an “urgent need for guidelines to protect them” (Sotoyama, Bergqvist, Jonai, & Saito, 2002, p. 135). This concern needs to be remedied quickly and this vulnerable population protected in order to reduce the risk of developing a musculoskeletal injury in a classroom environment (Shinn, Romaine, Casimano, & Jacobs, 2002).

2.3.3 Childhood LBP Link with Computer Use

Murphy et al. (2002) writes that “contrary to common belief, back pain amongst young people is a frequent phenomenon” (p. 365). Epidemiological studies have found high prevalence rates of back pain among schoolchildren (Murphy, Buckle, & Stubbs, 2002). This concern for childhood MSD is based on a body of evidence that has linked the occurrence of childhood MSD as a factor in adult MSD. Longitudinal studies have examined this trend and have shown that there is also significance in this early onset
pattern for LBP. A study by Smith et al. (2003) examined MRI’s of 10 year old children for spinal canal dimensions. During their research, they also that found there were disc abnormalities. A smaller sample analysis of 154 children was performed that showed 14 degenerative lumbar discs with signs of early bulging or tearing. These early degenerative changes were unexpected and the concern was that this early disc degeneration may affect the mechanical structure of the back and predispose the individual to muscle and ligament strains and sprains as well as arthritis of the spinal joints.

The links between faulty posture and causal and degenerative joint disease have also been shown. Knusel and Jelk (1994) reported that faulty posture during childhood is an important causal factor for the development of degenerative conditions of the spinal column.

2.4 Intervention verses Prevention

One area that has not received as much attention is the actual prevention of the occurrence of these disorders. Rather, intervention-based ergonomic solutions and educational programs have been developed. In a study of 55 respondents, 60% had exposure to workstation ergonomics information, but less than 10% used their knowledge in their task, even though 70% of them experienced symptoms associated with computer overuse (Berner & Jacobs, 2002).

Further studies have examined the success of interventions. An educational program involving 19 students with a mean age of 11.6 years found they were able to
improve the subject’s computer health knowledge as measured by pre and post tests (Rowe & Jacobs, 2002). Williams and Jacobs (2002) studied six children, with a mean age 12.7 years, and their parents during an education intervention that was designed to increase their knowledge of computer use and workstation setup. They were successful in increasing their computer knowledge but were not successful in changing postures.

In summary, for long term results, it would appear that the focus needs to shift from reactive intervention to earlier and proactive intervention (Smith, Jeffrey, and Porter, 2003) and most importantly to a program with a mandate for prevention.

2.5 Anatomical and Developmental Factors

In order to develop an understanding of how to prevent MSD, it is essential to look at the multiple and varied factors that make children a vulnerable population. There are both internal and external forces to be considered. A brief review of internal factors is appropriate in order to make the connection between anatomy, development and external influences.

It is important to remember that children and adult musculoskeletal systems are different (Harris & Straker, 2000). Children are less able to withstand stresses that are normal for the adult spine (Grimmer & Williams, 2000). Children are also more vulnerable to manual handling injuries because they are still developing (Whittfield, Legg, & Hedderley, 2001). There are several anatomical and developmental factors that must be considered when looking at posture, stresses and developmental stages for determining ergonomic recommendations. The stages could be divided into: infants, 3 to
2.5.1 Skeletal Structure

In determining risk to a developing child, it is important to understand the process and stages of that development. It is also important to identify which of these processes has the potential to be of concern for MSD. The first of these is the bony or skeletal structure itself. Basmajian notes that bones will ‘give’ with the ease of wrought iron and it will bear weight with the ease of ‘cast iron’. These qualities of elasticity and rigidity are due to its chemical composition. The organic matter component is one-third of bone mass and accounts for its toughness, elasticity or flexibility, while the inorganic matter of two-thirds accounts for bone hardness or rigidity. It is important to note that the relative amount of organic to inorganic matter changes with age. In childhood, organic matter is higher and thus during this period, bones will bend. An example would be rickets. This also explains why fractures in childhood are infrequent relative to the trauma that the bones are exposed to. It also explains why, when bones do break, the resultant breaks are not clean ones and are thus called green stick fractures. With increasing age, the amount of salts increases and the bones lose their elasticity resulting in clean fractures (Basmajian, 1982).
2.5.2 Growth Patterns

Children’s bones and spine grow at the growth or epiphyseal plate. This is an area of cell reproduction which results in lengthening of the bones from their ends as opposed to growth from the midshaft. This growth determines the length and shape of mature bones. Once the bones are mature, the growth plates fuse and are replaced by hard bone. Growth plates are thus the weakest link in growing skeletons. They are weaker and softer than ligaments and tendons and represent about fifteen percent of childhood fractures. Damage to children’s joints usually occurs at the growth plates and thus can affect future bone growth. If the growth plate is disturbed by a significant amount, the bone’s growth will be affected. Growth spurt periods are, therefore, particularly vulnerable due to the softness of the growth plate and bone mass weakness and because the tendons, ligaments and muscles are still developing. This means that they are unable to fulfill their adult role of contributing to joint integrity. It is also important to consider that following a growth spurt, bone growth undergoes a consolidation period where children learn posture and coordination and the soft tissues develop to accommodate their new growth (Basmajian, 1982).

Young children’s spines are different than older children’s because the bones are soft and the relationship between muscle and bone changes with development. In early adolescence the growth plates are growing bones and spines in length without adding mass. In mid-adolescence, the spine increases in volume without a corresponding increase in mass. In late adolescence, the child’s spine starts to increase in mass as the
growth slows. This can be a critical time for spinal curves developmentally. Several studies have examined this rapid physical growth period and noted that there appears to be a causal relationship between the early evolution of the degenerative processes of the lower lumbar discs and frequent low back pain in some subjects (Balague, Troussier, & Salminen, 1999; Harreby, Neergaard, Hesselsoe, & Kjer, 1995; Salminen, Erkintalo, Laine, & Pentti, 1995). Gender differences must also be considered since by the age of seven, a girl’s bones have reached 70% of their maximum length but they are only at 40% of their bone density, making them especially vulnerable to injury (Bass et al., 1999).

**2.5.3 Spinal Curves**

Spinal curves also vary at different developmental stages and with individuals. The two permanent or primary curves, that are concave forward or kyphotic, continue as the thoracic and sacral curves. Secondary convex forward curves or lordotic curves develop in the cervical and lumbar regions and are the result of developmental body changes. Infants are born without a lumbar curve but as they grow, it develops so that the centre of gravity of the body will not lie in a plane in front of the hip joints during a sitting or standing posture. In turn, the cervical curve develops in response to holding the head up (Basmajian, 1982). In adolescence, hormonal changes affect the distribution of muscle and fat and the external shape of our buttocks which then in turn further affects our lumbar curve.
Variation and change in spinal curvature is also due to the anatomical fact that, until around the seventh or eighth year, some of the vertebrae tend to be more wedge-shaped which increases the curve. Then, when the vertebrae begin to differentiate and square off, the curve decreases. As a result, before adolescence, about one out of five cervical spines are kyphotic. Children under the age of eight also have more neck motion because the ligaments are more lax, the muscles are weaker and the orientations of the shallow facet joints and cartilage have not yet ossified (Lueder, 2004).

A number of longitudinal studies have followed a large cohort of children to determine if there is a pattern to spinal curve formation. Several longitudinal studies have looked at the development of postural curves and spinal mobility during growth. Widhe (2001) looked at 90 children at the age of 5-6 years and again at 15-16 years. He noted that both the thoracic kyphosis and lumbar lordosis increased by 6 degrees and mobility decreased by 27 degrees in the thoracic spine and 4 degrees in the lumbar spine over the 10 years. The relationship between kyphosis and lordosis was independent of gender at age 5-6 but kyphosis relative to lordosis was significantly lower in girls among the 15-16 years olds. Analysis of interview data showed that 38% of the 15-16 years olds reported occasional low back pain and this was not related to gender, exercise, posture or spinal mobility.

Another study followed 1060 children annually over three years from 10.8 years to 13.8 years (Nissinen, 1995). The researcher found that there was a mean thoracic kyphosis increase and the mean lumbar lordosis decrease with age in both sexes but these
changes were not constant and there was wide individual variation. He also found that thoracic kyphosis was most pronounced at a mean age of 12.8 years and the lumbar lordosis was least pronounced at a mean age of 13.8 years. The same cohort was followed for 8 more years until the age of 22. Trunk asymmetry was prevalent in both young adult women and men, while at puberty, idiopathic scoliosis was twice as prevalent among girls as boys (Nissinen et al., 2000). They found that 30% of the adults were symmetric with a rib hump less than 4 mm in the forward bending test, 51% had a rib hump of 4 to 9 mm and 19% had a rib hump of 10 mm or larger. The asymmetry of a skew to the right at the thoracic level and then to the left at the lumbar level at puberty, remained constant at adult age. The prevalence of major trunk asymmetry (>10 mm) at adult age was the same in both men and women in contrast to increased trunk asymmetry in women at puberty. They concluded that the shape of the back mainly develops during the pubertal growth spurt at ages 12 to 14 years in both sexes (Nissinen et al., 2000).

2.5.4 Clinical Postures

Children’s postural patterns begin around age seven although there are a wide range of postures and movements typical of children. The conscious control of posture develops and initially it is categorized by over-correction, over-control and muscle tension (Lueder & Burt, 2002). Results of epidemiological studies of posture and MSD outcomes have not always been consistent. However, a literature review showed that posture was an independent risk factor for MSD among computer users (Gerr et al., 2004). A posture of kyphosis and rounded shoulders increased incidence of interscapular
pain and forward head posture increased the incidence of cervical, interscapular and headache pain (Griegel-Morris, Larson, Mueller-Klaus, & Oatis, 1992). It was also found that daily or weekly hours of computer use are more consistently related to hand and arm MSD rather than neck and shoulder MSD (Gerr et al., 2004).

Postural insufficiency was identified in study of 144 children aged 6 to 17 years as the reason for the shoulder centre moving forward in relation to the line of gravity. They also identified that a hollow round back showed a decreased ability to attain a sufficient posture and that the ability to achieve sufficient posture was correlated with age and that flexibility decreased with age (Ihme, Gossen, Olszynska, Lorani, & Kochs, 2002).

van der Heide et al. (2003) evaluated the development of postural adjustments associated with reaching movements in 29 sitting children ages 2-11 years and 10 adults and found that, with increasing age, the head becomes the dominant frame of reference and the anticipatory postural muscle activity, which was present in adults, was absent between the ages of 2-11 years. They suggested that the forward-tilted position is the most efficient in terms of postural control.

In a study that looked at the effects of multiple sitting postures on spinal angles, it was found that head orientation was maintained by compensatory adjustments in both the upper and lower cervical spine and changes in lumbar posture were associated with compensatory changes in the overall cervical position. If the lumbar spine moved into extension, the cervical spine flexed and if the lumbar spine flexed the cervical spine
extended. There was, however, variation in whether the cervical changes occurred in the upper or lower cervical region (Black, McClure, & Polansky, 1996).

Another important consideration is the fact that children are more flexible than adults which allows them to adopt postures that an adult would not use, for example lying prone on the floor to play on a laptop computer. This further increases the stresses and risk to their developing musculoskeletal system. The nature of the task for children also contributes to their risk in that students who are using the computer to complete an assignment or who are engrossed in a computer game may assume an awkward posture for prolonged periods in order to complete their task without taking a break. It is also important to remember that children will work at computers even though they are experiencing pain and that 26% of children surveyed reported that if they experienced discomfort they would continue using the computer (Harris & Straker, 2000).

Another consideration is the relationship between computer workstation posture and discomfort and which comes first. In a study of 68 school children using RULA to evaluate posture, Breen et al. (2007) found that posture became worse over time and that discomfort, as indicated by a body discomfort chart and modified visual analogue scale, correlated with higher mean RULA grand scores. However, they were unable to determine if the discomfort was from the computer use or from the sitting posture itself.

2.5.5 Muscular Developments

There are a number of considerations in the development of muscle control. Younger children have slower muscle relaxation rates; at age 3 the muscle relaxation
time is 90 ms vs. 40 ms at age 10. They also have slower rates of alternating rapid movements. Children’s muscle fibres are also smaller in diameter until at age 10 there is a significant increase in fibre diameter (Lin & Walsh, 1994). These factors may be important in cumulative loading and injury prevention. These are important factors to consider when developing guidelines for exposure time.

Children may also be more at risk due to their muscular immaturity. Zennaro et al. (2003) studied the right trapezius muscle on 14 subjects during normal computer work using a mouse for 30 minutes. They were testing the Cinderella hypothesis which proposes that there is continuous activity of specific motor units (MUs) during low-level muscle contraction. The MUs may then become metabolically overloaded with the subject developing muscle pain and strain. This occurs because the MUs must be active for a long enough time to damage muscle fibres. A long lasting MU activity was verified in some of the subjects and a substitution pattern was not observed. They concluded that, if continuous activity overloads low threshold MUs, the potential exists for selective fibre injuries to occur in low threshold MUs of the trapezius muscle in subjects who are exposed to long term computer work. Further research by Zennaro et al. (2004) looked at trapezius muscle activity during appropriate and inappropriate ergonomic desk adjustments and found a significant increase in MU activity was observed with the desk adjusted 5 cm higher than appropriate resulting in increased duration of the motor unit activity. Participants with severe symptoms activated more motor units and they were active longer. On average, the women activated more motor units, twice as long as in
men, during the same tapping task. They concluded that certain individuals who work with incorrectly adjusted workstations may be at greater risk of developing MSD due to prolonged activity of the MUs in addition to the motor demands of the task itself. In the immature and developing muscles of children and youth, this concept must be given consideration.

2.6 External Risk Factors

The external factors to be considered centre on the design features of the actual workstation and its components. These have received much attention in the literature with some consistent results. In analyzing the risk factors for MSD, one must consider the workstation design, placement of the computer equipment, type of furniture, type of computer equipment and their features. In the past, most of the research has examined the role of these factors on adult populations but not children. More studies are required to evaluate the impact of these factors on children. However, adult population studies can still be applied to children’s populations with the added caveat that children are further at risk due to their stage of development and tissue vulnerability. A brief summary of the current research is given for the different issues in terms of their identified risk factor for MSD followed by a summary of what the research has found specific to the related computer workstation component.

2.6.1 Computer Vision Syndrome

The American Optometric Association (AOA) has identified visual problems associated with computer use as Computer Vision Syndrome (CVS). CVS is a group of
eye and vision-related problems that result from prolonged computer use. Many individuals experience eye discomfort and vision problems when viewing a computer screen for extended periods and the level of discomfort appears to increase with the amount of computer use. The most common symptoms associated with CVS are: eyestrain, headaches, blurred vision, dry eyes, and neck and shoulder pain. These symptoms may be caused by: poor lighting, glare on the computer screen, improper viewing distances, poor seating posture, uncorrected vision problems or a combination of these factors (AOA, 2011).

Viewing a computer screen often makes the eyes work harder. As a result, the unique characteristics and high visual demands of computer viewing make many individuals susceptible to the development of vision-related symptoms. Some important factors in preventing or reducing the symptoms of CVS are related to the computer and how it is used. These include: lighting conditions, chair comfort, location of reference materials, position of the monitor, and the use of rest breaks (AOA, 2011).

Visual development in children occurs in stages. At birth, 80% of children are farsighted and this decreases with age until it normalizes by the age of 7-8. Near-sightedness then increases with increasing age. Children continue to develop complex visual skills as they mature and hand-eye coordination develops by ages 11-12 (Lueder and Burt, 2002). Lueder and Burt (2002) cite Ankrum and Fostervold’s overview of the research which showed that classroom schooling, requiring extensive or intense near vision, can contribute to the development of near-sightedness (myopia). Therefore, there
is reason to suspect that too-close viewing distances as in computer use, especially at high viewing angles, may increase long-term visual dysfunctions as children mature into adulthood.

This is supported by a study by Burgess-Limerick et al. (2000) where they concluded that optimal location of visual targets is at least 15 degrees below horizontal eye level after studying twelve subjects under various conditions. It was reported that visual strain is associated with higher placement of the visual display terminal (VDT) while musculoskeletal strain is associated with lower placement of the VDT. They concluded that the preferred VDT location corresponds to a location in which less neck discomfort is reported. Mid-level or somewhat higher placement is preferred, although for some individuals or tasks, optimal placement may be lower. It was also found that changes in VDT location cause large changes in atlanto-occipital posture and gaze angle. Cervical posture was altered to a lesser extent. However, it was noted that changes in backrest inclination resulted in changing cervical posture but not atlanto-occipital posture and gaze angle. They concluded that the posture used to view a target is a compromise between visual and musculoskeletal demands (Psihogios, Sommerich, Mirka, & Moon, 2001).

Another component of vision is its relation to posture. After studying 18 subjects and fatiguing their neck extensor muscles with eyes open and closed, it was shown that vision is able to overcome the effects of neck muscle fatigue and thus is necessary for postural control; compromised vision would therefore have postural effects (Schieppati,
Nardone, & Schmid, 2003). If this generation of children progresses to develop CVS and/or develops early onset myopia, they are at risk of further compromising their postural controls and thus increasing the demands on their musculoskeletal system.

2.6.2 Visual Display Terminals

The position and height of the VDT has been studied and is of significance for children, not only for its visual consequences but also because of the effect it has on the muscles of the neck and back. The effect of prolonged (89 minute) VDT work at four different screen heights on head-neck posture, muscle activity and the development of muscle fatigue were investigated. It was found that lowering the screen height, starting from 15 cm above the baseline (top of the screen level with eye height while sitting), decreased the ear-eye angle, increased the viewing angle relative to the ear-eye line and increased the muscle activity of the neck extensor muscles. It was concluded that one should pay extra attention to monitor height as that forced subjects to maintain excessively high visual fields (Seghers, Jochem, & Spaepen, 2003). A study of computer operators in eight different combined postures of visual target height and chair backrest inclination found that first, in order to minimize the musculoskeletal load, the gaze inclination to a visual target should be 6-9 degrees (range 0-15 degrees) below the horizontal and second, the gaze inclination is independent of a sitting posture with a backrest between upright and inclined 15 degrees backwards (Delleman & Berndsen, 2002). Another study examined ten subjects for the effect of computer monitor height on
the neck muscle activity, user comfort and acceptability. While there was no statistical difference between the mean RMS values for significant muscle EMG for the different heights, the user comfort and acceptability were all significant with the preference given at 15 degrees of downward gaze (Kothiyal and Bjornerem, 2009). Villanueva et al. (1997) looked at ten healthy subjects and found that at higher screen height settings, the neck became significantly more erect and the subjects also adopted a more backward-leaning trunk position.

### 2.6.3 Wrist Posture

A number of studies have examined wrist position as a predictor for MSD. Liu et al. (2003) found that computer workers who kept their wrists extended by more than 20 degrees were at greater risk of CTS. Keir and Wells (2002) found that 25% of maximal exertion is required of the wrist extensors when the wrist is extended to 30 degrees.

In a questionnaire and clinical interview study of 3500 workplaces in Denmark involving over 5600 workers, Andersen et al. (2003) found in cross-sectional comparisons and follow-up analyses, that there was an association between the use of a mouse for more than 20 hours per week and the risk of possible CTS. However, they found no association with keyboard use.

In a study of twenty subjects where EMG activity in the forearm muscles in positions of extension and ulnar deviation were measured, researchers found that self selected neutral wrist posture decreased the forearm muscle activity significantly (Fagarasanu, Kumar, & Narayan, 2004). Simoneau and Marklin (2001) also found that
downward sloping of the computer keyboard could be beneficial in prevention of MSD due to decreasing the angle of wrist extension.

In a surface electromyography (sEMG) study, researchers found that keyboard placement is important because flexor tendon forces during keyboard use may be as high as 60N/per keystroke due to low-force, high frequency activities. This level of tendon force represents approximately 1.8% of the tendon’s maximal force potential and thus is not sufficient to cause permanent damage to the tendon according to current cumulative strain models (Smutz, France, & Bloswick, 1995). This study would then support the multifactorial or cumulative load theory of MSD vs. a single factor.

2.6.4 Mouse Placement

The location of the mouse relative to the keyboard has been identified as a risk factor for MSD and CTS. Researchers have investigated the preferred positioning of the mouse and the effects of incorrect positioning on the surrounding musculature.

It has been noted that the presence of the numeric pad on the keyboard increases the distance on the right hand side. Seventeen subjects at an ergonomically-adjusted workstation were studied by measuring sEMG activity from four muscle groups. It was predicted that there was an overall increase in MSD and CTS when people abduct their arms in order to reach a mouse positioned to the side of a standard width or wider keyboard. They also noted that subjective reports of muscle tension did not correlate with sEMG activity (Harvey & Peper, 1997). The Cook and Kothiyal (1998) research also supported this finding when they used 10 subjects to look at mouse position in terms
of EMG and RULA. They found significantly less anterior and middle deltoid EMG activity without the numeric pad although the EMG activity of the trapezius muscle did not differ between positions. They concluded that the working posture of right handed mouse users was improved by removal of the numeric keypad. Delisle et al. (2004) also found that it was better to use a keyboard without the numeric keypad with the mouse on the right side.

Another study by Baker et al. (1999) revealed that increased muscular activity was found in the neck during the use of the mouse in comparison with the use of the keyboard. They felt that this was perhaps due to higher visual demands and suggested that changing the position of the mouse alone may not significantly reduce muscle contractions in the neck. A further study also showed that mental demands during computer work increased muscular activity and that use of the mouse increased muscular activity in the extensor muscles of the neck which could also be explained by higher visual demands associated with the use of mouse rather than a keyboard (Laursen, Jensen, Garde, & Jorgensen, 2002).

In regards to optimum mouse position with a non numeric keyboard, researchers examined 30 adults for wrist and upper arm postures and measured surface electromyography (sEMG) of four forearm muscles and three shoulder muscles. They concluded that a high mouse position as compared to the standard and central mouse position resulted in the least neutral position of the upper extremity posture and the highest level of muscle activity (Dennerlein and Johnson, 2006).
2.6.5 Keyboard Placement

Height of the keyboard can be an important factor in the working posture of the user (Liao & Drury, 2000). Keyboards that promote a more natural hand position while typing reduce the potential for a MSD of the wrist (Zecevic, Miller, & Harburn, 2000). Reduced risk of neck and shoulder MSD is reported after lowering the height of the keyboard to or below the height of the elbow and resting the arms on the desk surface or chair armrests (Gerr et al., 2004).

2.6.6 Forearm Posture

The role of the forearm in contributing to the injury mechanism in MSD has been well documented. A number of studies have concluded that a neutral forearm posture with a relaxed and supported arm on an adjustable arm rest reduced the perceived exertion and EMG activity of the forearm, arm, neck and shoulder muscles (Aaras et al., 1997; Cook & Burgess-Limerick, 2004; Karlqvist et al., 1998; Lintula et al., 2001; Straker et al., 2008).

Using a questionnaire, 6943 computer workers in Denmark were surveyed at baseline and one year later. It was found that an increased risk of forearm pain was associated with the use of a mouse device for more than 30 hours per week and with keyboard use of more than 15 hours per week. High work demands and time pressures were also risk factors and women were found to have a twofold increased risk of developing forearm pain (Kryger et al., 2003).
Karlqvist et al. (1998) found that short and narrow shouldered operators worked in more strenuous postures of the arm when the mouse was located lateral to the keyboard. They found that arm support successfully reduced muscle load in the neck and shoulder region. These results have implications for children as well due to their smaller stature.

Height adjustable arm rests of the chair is another consideration. When adjustable armrests (22 to 28 cm) were studied using sEMG and a questionnaire, it was found that armrests were effective in alleviating muscle strain in computer operators when they worked at non adjustable desks or when operators could not rest their wrists on the desk (Harreby et al., 1999; Hasegawa & Kumashiro, 1998). No studies were found that examined arm-rest adjustability in terms of abduction from the body.

2.6.7 School Furniture and Anthropometrics

Anthropometric considerations have been considered fundamental in the prevention of MSD. The correctly adjusted ergonomic workstation is central to the prevention of MSD in adults. In the past, research studies have examined children, anthropometrics and school furniture. Several large studies have concluded that children do not work in a school environment where anthropometric matching exists. Panagiotopoulou et al. (2004) took anthropometric measures of 180 students (ages 7 to 12 years) from three primary schools in Greece and compared them with 4 different types of chairs and 5 different types of desks available in the school system and found that there was a mismatch between the students’ bodily dimensions and the classroom furniture.
available to them. The chairs were too high and too deep and the desks were also too high for the pupils. They felt that this had negative effects on the sitting posture of the children especially, when reading and writing. Parcells et al. (1999) concluded there was a substantial degree of mismatch between the students’ bodily dimensions and the classroom furniture available to them when they looked at 74 students in Michigan ages 10 to 14 years old. They measured three styles of chairs and three styles of desks and found that fewer than 20% of students could find acceptable chair/desk combinations. Most of the students were sitting in chairs with seats that were too high or too deep and desks that were too high. After controlling for body stature, girls were less likely to find ergonomically suitable chairs. They concluded that many 6th graders were working in conditions that were not conducive to learning. Saarni et al. (2007) examined 101 twelve and fourteen year old students in Finland and found that there was a mismatch between the school furniture and the anthropometrics of the schoolchildren. Cotton et al. (2002) concluded ethnicity played a significant role in seat height in a study of grade 6, 7 and 8 students and felt that these disparities may “create a generation with an increased incidence of musculoskeletal problems carrying over to adulthood and the adult workplace”.

The significance of this mismatch lies in the relationship between mismatched school furniture and both child and adult postural concerns with associated back pain. Schroder (1997) writes that inadequate school furniture is often taken to be the cause of severe posture problems in adults and, therefore, chairs and desks need to be evaluated
carefully. Milanese and Grimmer (2004) studied 1269 school children and found that there was an overall higher odds ratio of reporting low back pain in the tallest students. They concluded that, while there was a multifactorial nature of causality of adolescent spinal symptoms, they believed that the degree of mismatch between child anthropometry and school furniture setup, should be examined as a plausible “associate” of low back pain.

In a paper which outlined the main ergonomic requirements for work chairs, several criteria were determined: safety, adaptability, comfort, practicality, durability and suitability for the job. Of particular importance was the conclusion that the chair’s dimensions and control features should meet the anthropometric characteristics of at least 90% of the potential users (Occhipinti, Colombini, Molteni, & Grieco, 1993).

Determining which anthropometric measurement will ensure a match is also an important consideration. Body height has been the traditional choice. When Molenbroek et al. (2003) looked at the anthropometric design process of school furniture for European children, they found that popliteal height instead of body height was a better fit and recommended that for Dutch children an extra large size is required from the European standard.

The significance of this anthropometric match and injury prevention is confirmed in a study by Zennaro et al. (2004) where they examined trapezius muscle activity during appropriate and inappropriate ergonomic desk adjustments. They found that a significant increase in MU activity was observed when the desk was adjusted 5 cm higher than
appropriate and this was due mainly to increased duration of the motor unit activity. Participants with severe symptoms of MSD activated more motor units and they were active longer. On average, the women activated more motor units, twice as long as in men, during the same tapping task. They concluded that certain individuals who work with incorrectly adjusted workstations may be at greater risk of developing MSD due to prolonged activity of the MUs in addition to the motor demands of the task itself.

2.6.8 Sitting Postures

Computer workstation tasks take place in a seated posture. Knight and Noyes (1999) identified that children spend a large part of their school days in the classroom, yet the effect of school furniture design on their behaviour and health had not been examined. They recommended that children should be given more choice in their seating and better guidance should be given to those involved in education in order to improve their decision making about classroom furniture and the postural, anthropometric and orthopaedic aspects of sitting and related activities.

The concern for sitting posture is its role in pain and injury. Sitting has been recognized as the main aggravating factor of low back pain (Balague, Dutoit, & Waldburger, 1988; Troussier, Davoine, de, Fauconnier, & Phelip, 1994; Troussier et al., 1999). Sitting and back pain have been associated in several studies. Salminen (1984) in a study of 370 children aged 11 – 17 years reported a prevalence of current neck and/or back symptoms of 20%, with 58.9% of those reporting pain while sitting. A significant
difference was also found between prevalence of low back pain (LBP) in the sitting versus the standing position, lying or walking.

In another study of 1503 children aged 14 years, Salminen et al. (1992) found that 38.9% of the subjects with recurrent LBP reported that sitting for over 30 minutes at school was troublesome and 28% reported the same for home. This group also reported a significant difference in the frequency of LBP in the sitting position verses standing, lying or walking.

What is important in terms of sitting posture is: 1) identification of the sitting posture that increases or decreases pain, and 2) what area of the body is affected by which posture.

The issue is its effect on spinal structures. In a study using a three dimensional static model, compression on the fifth lumbar disc was calculated in different seating positions. The lowest disc compression was found with the seat pan and backrest reclined while postures with forward bending had the highest disc loading (Kayis & Hoang, 1999).

From the literature, children assume several postures while sitting. In a survey of schools in Denmark, children spent their sitting time equally in backward-leaning and forward-leaning positions (Storr-Paulsen & agaard-Hensen, 1994).

The postural patterns to produce pain have also been studied. Murphy et al. (2004) found an association between flexed postures and low back pain when looking at sitting postures of 66 children aged 11-14 years. Static postures of the neck and upper
back were also found to be related to low back pain. Back pain has been found to be correlated with tightness of the thigh muscles but researchers have been unable to correlate spinal mobility and flexibility of the muscles and joints with back pain (Balague et al., 1999). Tightness of the thigh muscles would be increased by assuming a sitting posture for extended periods of time and thus prolonged sitting postures could become a risk factor.

Postural patterns that affect muscle activity have also been studied. Villanueva et al. (1997) reported that increased flexion of the neck results in increased activity of the neck extensor muscles. A backward leaning of the trunk also decreases the trapezius muscle activity. They concluded that neck and shoulder muscle activity relates to neck angle and trunk inclination.

In a study that looked at the effects of multiple sitting postures on spinal angles, it was found that head orientation was maintained by compensatory adjustments in both the upper and lower cervical spine and changes in lumbar posture were associated with compensatory changes in the overall cervical position. If the lumbar spine moved into extension, there was a corresponding movement of cervical spine flexion and if the lumbar spine flexed the cervical spine extended. There was, however, variation in whether the cervical changes occurred in the upper or lower cervical region (Black, McClure, & Polansky, 1996).
Sitting postures and their implications are increasingly important in a generation where Canadian children and youth spend 62% or 8.6 hours per day of their waking hours in sedentary activities (AHK Report Card, 2011).

2.7 Other Factors

A further consideration in the understanding of MSD in children and youth is the addition of other factors such as obesity and psychosocial factors as well as commonly observed pain patterns. A brief review is given of relevant literature.

2.7.1 Obesity as a Risk Factor

The Canadian Community Health Survey (CCHS) (2005) reports that among young people, the greatest increases in obesity rates over the past 25 years occurred among adolescents aged 12 to 17, where the rate tripled from 3% to 9%. The survey also found that among children aged 6 to 17, the likelihood of being overweight or obese tended to rise with time spent watching TV, playing video games or using the computer. This cycle of inactivity and sedentary activities and obesity is somewhat self perpetuating. What is of concern is the role of obesity in MSD. The increased weight load on joints due to obesity may contribute to long term tissue damage as well as structural changes in skeletal and muscle development due to the immature nature of the tissues. Decreased physical activity levels due to time spent on the computer as a contributing factor to obesity have also been identified as a risk factor. Another mechanism by which obesity may contribute to the risk of MSD is the fact that increased
adiposity is a well-recognized risk factor for tendon injuries in adults. The mechanisms may be excessive biomechanical load and/or the low inflammatory condition caused by excess body fat. However, this issue has not been investigated in children. A three year study is being conducted to investigate if children (aged 8-12) with elevated body mass index (BMI), total body fat percent and abdominal fat percent experience more overuse injuries than 'normal' children, taking into account sport participation and physical activity (Klakk, Jespersen & Wedderkopp, 2011). The results of this study could have implications for further advocating physical activity and weight reduction in children for the prevention of MSD.

2.7.2 Television Watching

Research into television watching and children has been examined in a number of studies. Results of these studies have identified risk factors that may be relevant to computer use. Issues such as posture, inactivity, pain, and obesity have all been examined. There is also an interesting possibility that the combination of television with daily computer use may increase the risk of the dose–effect relationship.

Two cross-sectional studies have shown that there is a significant correlation between the time spent watching television and back pain. They found a prevalence of back pain of over 50% in children who watched more than one hour per day and found that this association could be related to prolonged sitting posture and/or to bad posture and/or to lack of physical activity (Balague et al., 1988; Balague et al., 1994; Troussier et al., 1994). Data used in the Active Healthy Kids Report Card 2005 state that one-half of
Canada’s children and youth spend two to four hours per day watching television. Researchers have found that children who watch more than 2 hours of television per day are more likely to be overweight and obese (Tremblay & Willms, 2003). This would appear to happen because television displaces other activities and because it is a time of unhealthy eating habits and children are being exposed to unhealthy food advertisements (AHK Report Card, 2005). This was supported by a study in Australia of 2862 children, ages 5-13 years, that reported the odds of being overweight and obese increased with increased television viewing (Wake, Hesketh, & Waters, 2003). It was also found that males report higher total screen usage but females rank higher for computer use across Canada. Children of lower income families also have higher television viewing time (AHK Report Card, 2005).

2.7.3 Psychosocial Considerations

The psychosocial aspect of pain and its long term consequences is another important consideration. In fact, one study found that children who suffered from idiopathic musculoskeletal pain reported a lower level of well-being than children suffering from rheumatoid arthritis (Sherry et al., 1991). Other consequences to chronic idiopathic pain, both long and short term, include depression, lack of physical activity, obesity, poor school/work performance and low self esteem, all risk factors themselves. This combination further contributes to the establishment of a pain/function cycle. From a different perspective, psychosocial factors can in turn increase muscle tension and increase task-related biomechanical strain, physiological vulnerability or symptom
reporting and may increase children’s risk (Buckle & Devereux, 2002; Murphy et al., 2004). Further, Brattberg (1994), in a cross sectional study of 1245 children and adolescents, aged 8 – 17 years, found that psychosocial and emotional factors were more important than physical parameters in predicting low back pain. Thus, the consideration of psychosocial factors is an area for further investigation.

2.7.4 Low Back Pain and Computer Use

The relationship between computer use, posture and low back pain (LBP) has been studied by a number of researchers attempting to reduce health care costs. The origins of LPB have been studied to assess prevention initiatives. A cohort study in Denmark (n=640) suggested that there was a positive correlation between a history of LBP during adolescence and presence of lumbar pain as an adult 25 years later (Harreby, Neergaard, Hesselsoe, & Kjer, 1995). In studies that looked at populations with over 300 children or more, the lifetime prevalence of back pain varies between 30% and 51% (Balague et al., 1999; Harreby et al., 1995).

Adolescent origins of LPB have significant implications for adolescent computer users who sit for extended periods of time. The cumulative effect of discal loading and viscoelastic forces, have yet to be determined in adolescents. Research in adults has shown that adult workers who are asked to maintain static flexed postures of the low back for extended periods of time, may increase the strain of the elastic, ligamentous tissues which in turn may have a deleterious effect on the stability of the spine and the normal reflex response of spinal tissues (Shin, Shu, Li, Jiang, & Mirka, 2004). This finding is
also supported by a study using a three dimensional static model whereby low L5/S1 disc compression was found with seat pan and backrest reclined while postures with forward bending had the highest L5/S1 disc loading (Kayis & Hoang, 1999).

Young children and adolescents do not appear to be different than adults in their incidence of LBP. Harreby et al. (1999) in a cross-sectional study looked at 1389 13 to 16 year old Danish school children through a survey and found a cumulative life-time prevalence of LBP of 58.9%, a one year prevalence of 50.8% and an increase in LBP of 6.4% from 14 to 15 years of age, independent of gender. In Canada, the annual incidence of substantial LBP was found to be 17.2% among a cohort of 377 adolescents with an average age of 13.8 years in a study by Ehrmann Feldman in 1998 (Balague et al., 1994).

A gender effect has also been demonstrated. The prevalence of back pain appears to be higher among girls than boys. Salminen et al. (1992) reported an increased prevalence of spinal pain among girls compared with boys between the ages 11 and 17.

Murata et al. (2002) looked at radiographical data and found that the lumbar lordosis and sacral inclination of youth today were approximately ten degrees larger than they were 10 years ago in both men and women. This was in contrast to no significant difference among adults today and those of the same generation 10 years ago. They noted that among Japanese youth, height has increased and back muscles have become weaker than 10 years ago.

The role of computer use in LBP is considered significant both in the short and long term and perhaps as a developmental factor in the spinal curves, muscular activation
patterns and pain patterns. As LBP contributes substantially at the adult level for health care costs, the potential for increased costs, due to early onset LBP in children, has significant implications and the role of computer use in this equation is also significant.

2.7.5 Headaches and Upper Back and Neck Pain

Headaches and associated upper back and neck pain are well documented in school age children. Causes that have been identified are musculoskeletal tension and fatigue. Other factors such as poor ergonomics combined with cumulative exposure and developing postural controls might increase this risk.

Three large studies were found that examined headaches in children. In a questionnaire study of 1290 six and seven year olds, the start of school appeared to increase the incidence of overall headache (occasional headache in particular) in children, independent of other factors (Anttila, Metsahonkala, & Sillanpaa, 1999). In a questionnaire study of 1135 Finnish 12 year old school children, researchers concluded that episodic tension-type headache is as common as migraine headaches in children and that tension headaches can be associated with depression, oromandibular dysfunction and muscular stress. In a cross-sectional study of 2815 Dutch schoolchildren between the ages of 9 and 17 years, researchers found that 22% reported weekly headaches. Children with the highest headache severity reported the lowest Quality of Life in general as well as numerous other problems, including the impact of headache on activities of daily living, leisure, other physical symptoms and social functioning (Bandell-Hoekstra et al., 2002). Children with frequent headaches report symptoms that are not conducive to
learning including stabbing and severe occipital pain, phonophobia and abdominal pain significantly more than children with infrequent headaches (Anttila et al., 2002).

It is important to consider that headache frequency is associated with neck stiffness and neck ache (Blizzard, Grimmer, & Dwyer, 2000). In a study looking at the relationship between neck pain/discomfort and range of motion, it was found that early range of motion changes and lower neck muscle endurance times were associated with the development of neck pain (Lee et al., 2004). The role of the neck and shoulder muscles were examined by Murphy et al., (2004), who found evidence that neck MSD were related to prolonged durations of static contraction of neck/shoulder musculature or posture.

In a study of 515 Finnish workers the annual incidence of neck pain was 34%. Poor physical work environment, poor placement of the keyboard, female sex, smoking, mental stress and less physical exercise were all found to increase risk (Korhonen et al., 2003). As identified earlier all of these risk factors can be found equally in children, including smoking.

2.7.6 School Performance

An often overlooked consequence of discomfort/pain is the effect on school performance. Several researchers have examined this relationship. Salminen (1984) found poorer school performances among subjects who reported cervical and/or lumbar pain and Balague et al. (1994) found an association between lumbar pain and school grade-point average.
Another study reported that children show a modest but significant improvement in on-task behaviour and a marked change in sitting posture with new ergonomic furniture (Knight et al., 1999). Work environment is also an area to consider when looking at speed, accuracy and performance and the proper work-rest schedule is an important factor in the management of musculoskeletal symptoms and performance. In a study of ten college students, a variety of work-rest schedules were tested on a data task and a mental arithmetic task. The 15 minute work/micro break schedule resulted in significantly lower discomfort in the neck, lower back and chest and resulted in the highest speed, accuracy and performance for both of the tasks (Balci & Aghazadeh, 2003).

2.7.7 Parental Issues

A study of home computer workstations by Kimmerly and Odell (2009) concluded after interviewing ten families that, while parents had positive attitudes about computing in terms of access to information and schoolwork, their concerns were: access to pornography, interaction with strangers, computer addiction, commercial exploitation and visual strain. Musculoskeletal injuries were not considered a concern and parents were not aware that typing and using the mouse may affect their child’s health. This raises the issue of the importance of education and ergonomic awareness for parents in order for any changes to be successfully implemented.
2.8 **Summary**

There are many statistics and studies to show that the frequency of MSD and the costs associated with them is of great concern. This concern has rightfully been extended to children and adolescents.

There are also numerous studies showing that children and adolescents are experiencing the same symptoms as the adult population and are subject to the same risk factors. Their risks are compounded by their vulnerable musculoskeletal system and their ergonomically incorrect environment that is increasing their potential for injury, both short and long term.

At the same time, there is increased understanding of the causes and contributing factors of MSD and thus the potential for successful interventions and prevention programs is greatly enhanced. The benefits and necessity of such proactive actions have been discussed. This study will further increase our knowledge of what postures children are assuming while working at adult computer workstations so that we can initiate appropriate and effective interventions and preventative programs.
CHAPTER 3
METHODS

3.1 Design of the Study

A laboratory experiment with a repeated measures design was conducted to evaluate the postures of children while playing a computer game at two different computer workstation setups: a child-adjusted workstation and an adult-adjusted workstation.

3.2 Participants

The participants were chosen as a sample of convenience from a group of parents and children who were willing to participate in the study. After receiving ethics approval from Queen’s University Ethics Review Board (Appendix A), nine participants (seven girls and two boys), ages 8 (n=1) and 9 (n=8) years, were recruited. The inclusion criteria were: no parental or self reported spinal, shoulder, elbow, wrist or arm pain and in good health. The exclusion criteria were: left handedness, unhealthy and a history of a musculoskeletal disorder or recent injury in the past three months. The study was explained to both parents and participants and information letters with a consent form were provided (Appendix B). Consent forms were signed for willing participants by their parent or guardian and each participant was asked to give verbal assent. During the consent process, parents were also asked to complete a modified National Longitudinal
Survey of Children and Youth 2002/03 (NLSCY) (HRSDC & Statistics Canada, 2002/03) (Appendix C). Results of these data are provided in Chapter 4, Table 1.

The anthropometric measurements of relevant body segments were taken. These included: age, stature, weight, waist breadth, hip breadth, hand length, lower arm length, upper arm length, knee height (seated), forward reach to grip, elbow height (seated), upper leg length, shoulder height, and thigh clearance. The specifics of the measurements that were taken are illustrated in Appendix D (CHILDATA). Results were obtained and recorded for the participants (Appendix E, Table 2). These data were used to adjust the chair and computer workstation to the appropriate dimensions for the child-adjusted workstation.

3.3 Work Station Set-up and Instrumentation

Two workstations were needed to complete this study; an adult-adjusted workstation (AAW) and a child-adjusted workstation (CAW). The adult chair was a generic Global® office chair which was in a constant position of 21 inches (53.5 cm) seat pan height from the floor and arm rest height at 11 inches (28 cm). The children’s chair was custom-made by Global® Furniture Company to our specifications for the anthropometrics of an 8 and 9 year old (CHILDATA) (Figure 1) and was adjusted for the participant. The Ergo-Growth™ adjustable desk was purchased from MyEliteKids (Fremont, CA.) because it had a large working surface area and a gas lift for adjustable desk height from 20 (52 cm) to 30 (76 cm) inches to accommodate both AAW and CAW height requirements (Figure 2). The desk height was adjusted for the child’s
measurements and the adult desk height was constant at the standard 29 inches (74 cm). Different computer systems were used to accommodate the size requirements as well. A standard adult mouse and a specific child size mouse were used (Figure 2). The children’s keyboard without a numeric pad measured 11.5 inches (30 cm) and the adult keyboard with numeric keypad was the standard 18.5 inches (47 cm) (Figure 2). The adult desk layout was a desktop computer, 17 inch monitor, adult keyboard, adult size mouse and mouse pad. The children’s desk layout was a desktop computer, 15 inch monitor, a children’s size keyboard, child size mouse, and mouse pad (Figure 4).
Figure 1. Two Global® chairs were used with the child version customized for 8 and 9 year old anthropometrics.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Adult</th>
<th>Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Back Width</td>
<td>19 inches (48 cm)</td>
<td>16 inches (41 cm)</td>
</tr>
<tr>
<td>B) Back Height</td>
<td>15 inches (38 cm)</td>
<td>13.5 inches (34 cm)</td>
</tr>
<tr>
<td>C) Seat Depth</td>
<td>19 inches (48 cm)</td>
<td>16 inches (41 cm)</td>
</tr>
<tr>
<td>D) Seat Width</td>
<td>20.5 inches (52 cm)</td>
<td>19 inches (46 cm)</td>
</tr>
<tr>
<td>E) Arm Height Range</td>
<td>10.5 (25 cm) – 13.5 (34 cm)</td>
<td>7.5 (19 cm) – 11 (28 cm)</td>
</tr>
<tr>
<td>F) Seat to Floor Range</td>
<td>18.4 (47 cm) – 23.5 (60 cm)</td>
<td>13.5 (34 cm) – 16.5 (42 cm)</td>
</tr>
</tbody>
</table>
The Liberty 3Space® Fastrak™ (Polhemus, Cochester, VT, U.S.A.) electromagnetic device was used to measure the position and orientation of eight sensors in 3D space. Using Labview 6.1 (National Instruments, Texas, U.S.A.), a data acquisition program was created to acquire and record data from all sensors at 30 Hz/channel. The Labview data acquisition program was designed to receive the participant’s file name and trial information, down-sample to 2 points per second, and then append the data from 8 sensors to this file every minute for 20 minutes. Appending to a file caused an overall
loss of 0.03666 seconds loss of data per minute or 0.73333 seconds of data loss over the entire 20 minute trial. Given the slow postural movements that occur during seated work, this loss was not considered important.

The participant was situated 1 m to the right of the source such that there was a 1 cubic meter working envelope. According to the Fastrak’s specification, the standard unit has a range of 1.5 m with accuracy in position of 9.1 mm and in orientation of 0.15°. The participant was situated in the positive quadrant on all three axes. The orientation of the source and sensors on the participants defined a right-handed coordinate system with X right, Y forward, and Z up. Therefore, rotations about X, Y and Z, represented flexion/extension, lateral bending, and axial rotation respectively. The naming of movements was adjusted based on the joint involved. For example, lateral bending was called abduction/adduction for the shoulder and rotation in the wrist was called ulnar and radial deviation (Figure 3).
A JVC digital video camera (GR-DVL 9800) mounted on a tripod was used as a collaborating reference to record the participant sessions. It was placed at a predetermined distance and position marked with tape on the floor to record the participant’s posture. An Olympus digital camera (Stylus 410) was used to record events and postures for display purposes only (Figure 5).

The pre-selected computer game, Jump Start Advanced 3rd Grade, Fundamentals™ (http://www.knowledgeadventure.com) was selected because it was age-appropriate, fun, educational, and met the stringent criteria of having: 1) a consistent variety and range of mouse activity throughout the game, 2) was available in the school system as an approved game, 3) appealed to both genders, 4) was able to keep the children’s attention for a 40 minute period, 5) had sound and visual effects, and 6) allowed for a variety of skill levels.

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<table>
<thead>
<tr>
<th>Joint Angle</th>
<th>Rz</th>
<th>Ry</th>
<th>Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist</td>
<td>Pronation/supination</td>
<td>Flexion/Extension</td>
<td>Radial/Ulnar Deviation</td>
</tr>
<tr>
<td>Elbow</td>
<td>Pronation/supination</td>
<td>Abduction/Adduction</td>
<td>Flexion/Extension</td>
</tr>
<tr>
<td>Shoulder</td>
<td>Internal/External Rotation</td>
<td>Abduction/Adduction</td>
<td>Flexion/Extension</td>
</tr>
<tr>
<td>Neck</td>
<td>Rotation</td>
<td>Lateral Bending</td>
<td>Flexion/Extension</td>
</tr>
<tr>
<td>Thoracic</td>
<td>Rotation</td>
<td>Lateral Bending</td>
<td>Flexion/Extension</td>
</tr>
<tr>
<td>Lumbar</td>
<td>Rotation</td>
<td>Lateral Bending</td>
<td>Flexion/Extension</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Segment Angle</th>
<th>Rz</th>
<th>Ry</th>
<th>Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>Pronation/supination</td>
<td>Flexion/Extension</td>
<td>Radial/Ulnar Deviation</td>
</tr>
<tr>
<td>Forearm</td>
<td>Pronation/supination</td>
<td>Abduction/Adduction</td>
<td>Flexion/Extension</td>
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<td>Arm</td>
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<td>Abduction/Adduction</td>
<td>Flexion/Extension</td>
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<tr>
<td>Shoulder</td>
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<td>Flexion/Extension</td>
</tr>
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<td>Head</td>
<td>Rotation</td>
<td>Lateral Bending</td>
<td>Flexion/Extension</td>
</tr>
<tr>
<td>C7</td>
<td>Rotation</td>
<td>Lateral Bending</td>
<td>Flexion/Extension</td>
</tr>
<tr>
<td>T12</td>
<td>Rotation</td>
<td>Lateral Bending</td>
<td>Flexion/Extension</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Rotation</td>
<td>Lateral Bending</td>
<td>Flexion/Extension</td>
</tr>
</tbody>
</table>

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**Figure 3: Reference chart for joint and segment angles**

The table above illustrates the joint and segment angles measured during the study.
Adult verses Child Workstation

**Adult Chair, Adult Desk Height, Adult Monitor, Adult Keyboard, Adult Mouse**

**Child Chair, Child Desk Height, Child Monitor, Child Keyboard, Child Mouse**

Figure 4  Difference between AAW and CAW setup.
Figure 5. Recording setup up and sample of a participants AAW wrist data collection.

3.4 Testing Protocol

Prior to data collection, a number of checks were made on the set-up and instrumentation (See Appendix F). Participants chose the order of their workstation randomly and this resulted in five working on the adult workstation first and four working on the child workstation first. The participants were asked to secure their hair off of their shoulders and were provided with a short sleeved t-shirt to wear. Anthropometric measurements were recorded.

The eight sensors were firmly attached to the body segments with double sided tape with three upper arm sensors at the estimated mass centre of the right hand, right
forearm, and right arm (Figure 6). These sensors were then secured in position using Mefix™ tape and Surgifix™ sleeves. To track motion of the head, one sensor was fixed inside a mold and was attached to the front brim of a ball cap (Morphett, Crawford, & Lee, 2003). Four sensors were used to quantify trunk motion. They were attached to the spinous process of C7, the spinous process of T12, the lateral iliac crest and the acromion of the shoulder using the double sided tape and the Mefix™ tape (Figure 6).

![Sensor placement](image.png)

**Figure 6. Sensor placement.**

**3.5 Procedures**

Participants were tested under two conditions that were randomly assigned: one at a standardized adult workstation with adult computer equipment and one at an ergonomically-adjusted children’s workstation with children’s computer equipment.
(Figure 4). For the CAW, the children’s anthropometric measurements were used to ergonomically adjust the height of the desk and chair for their particular measurements.

Prior to recording data and for bore sighting purposes, participants were asked to stand in “attention” posture with their palms facing in toward their thighs and their eyes looking straight ahead. The participants then seated themselves at the computer workstation. They were then given verbal instructions to “play the computer game as if they were at home and to move around according to how they would behave at home”. Participants were allowed to play the computer game at their own pace and ability. They were allowed to play for 3-5 minutes in order to become familiar with the computer game and to adjust their postures to suit the workstation and equipment. Without indicating the start time, data collection was initiated by turning on the Fastrak™ program and video camera simultaneously for 20 minutes of continuous sampling.

At the end of the first time period, the cables were placed in a small backpack so that the participant could move around while still leaving the sensors attached. The participants were then asked to complete a Visual Analogue Scale (VAS) (Appendix G) and Child Rate of Perceived Exertion (PCert) (Appendix H) as it applied to that workstation. The participants were provided with a light snack and a juice box. Also during this time period, the workstation was set up for the next session as either AAW or CAW. Computer equipment was exchanged to either child or adult between sessions as well.
After a ten minute break, the participants were re-connected to the Fastrak™ 240/8 system and conductivity checks were made. Participants were allowed to position themselves in the appropriate chair for their second randomly-selected workstation. The participants were allowed 3-5 minutes to become familiar with their workstation and chair again and given the same instructions prior to data acquisition, “play the computer game as if they were at home and to move around according to how they would behave at home”. Participants were again bore sighted in the position of “attention” with palms facing inwards towards their thigh and eyes straight ahead. Data collection was halted after 20 minutes. The participants were asked to complete a Visual Analogue Scale (VAS) and Child Rate of Perceived Exertion (PCert) as it applied to their workstation. The instrumentation was then removed and the participants were given the t-shirt to keep.

3.6 Data Processing and Analysis of Objective Measures

A Labview 6.1 software program (National Instruments, Texas, U.S.A) was developed by Dr. Mohammad Abdoli for viewing and data analyses. The text files were read into this program, reorganized according to sensor Px, Py, Pz and Rz, Ry, Rx. This resulted in data in 3 displacements (X,Y,Z) and 3 orientations (Rz, Ry, Rx) for the pelvis, T12, C7, hat, shoulder acromion, arm, forearm and hand. A rotational transformation matrix was used from the global Fastrak source to the local body coordinates based on the standing soldier posture. Then, Euler angle sequence rotations were used to create a decomposition matrix to determine segment and joint angles. The segment (absolute) angles with respect to the reference frame were: hand, forearm, arm, shoulder, head tilt,
upper trunk, lower trunk and pelvis. Each segment angles data file consisted of 2400 data points per file.

The joint (relative) angles were: wrist, elbow, shoulder, cervical, thoracic and lumbar. Once calculated, the joint angles were downsized again by averaging 24 consecutive points to yield 100 points. This step was completed for ease in further analysis in Excel and graphing. To confirm that this data reduction step did not adversely affect the data, means were taken as well as a visual comparison of one segmental orientation of one trial (Figure 7). The mean differences between sampling methods was 4.998 degrees for 2400 data points and 4.945 degrees, an average loss of 0.0106 degrees. This loss was not considered sufficient to affect the overall results.

![Comparison of 2400 Data Points vs. 100 Data Points](image)

**Figure 7.** A comparison of a 100 point sample (red) vs. a 2400 point sample (blue). Note that the red vertical lines have been added for easier viewing.
Once the data were easily accessible inside Microsoft Office Excel 2007, joint angle data were reviewed looking for numeric values that were not consistent within the range for inter-participant and intra-participant. Histograms were also reviewed to examine for consistency in the data within the range for inter-participant and intra-participant. Data trials were rejected based on criteria that were: 1) not consistent values when compared with other participants for the same workstation, 2) not reasonable anatomical values for angles and 3) could not be corroborated with recorded video analysis. This screening process resulted in two subjects being removed from the data set due to data that did not meet the inclusion criteria and indicated that the sensors had been disturbed or moved or instruments were not recording reliable data. For each condition (AAW and CAW) of each participant, mean values, standard error of the mean, and standard deviations were calculated. Then, for graphing purposes, these summary statistics were averaged across all participants to report a grand mean, grand error of the mean and grand standard deviation for AAW and CAW conditions.

Participant summary statistics were then analyzed in Excel using two tailed paired t-tests (p<0.05) to determine if there was significant difference in the angles between the two workstations. A Bonferroni adjustment of the significance level for the null hypothesis was not considered in order to balance the tendency to increase type 2 errors (false negatives) while minimizing type 1 errors (false positives) (Perneger, 1998; Rothman, 1990; Weber, 2007). In addition, this study was considered exploratory and descriptive in nature and, therefore, no tendency for significance should be overlooked at
this early stage in the investigation (Perneger, 1998; Rothman, 1990; Weber, 2007). However, it is realized that the sample size is extremely small for such a large number of variables.

3.7 Data Analyses and Processing of Subjective Measures

The VAS used was a child-adapted pain scale that showed faces to reflect mood and rating of discomfort and pain levels with five being the highest (Appendix G).

The PCert used was a child-adapted measure designed to assess rate of perceived exertion. It used images and faces and a 10 point Likert scale to rate discomfort and effort with anchors of one (very, very easy) and ten (so hard, I’m going to stop) (Appendix H).

The National Longitudinal Survey of Children and Youth 2002/03 (adapted) was used to collect information from the parents on their child’s access to a computer, hours of computer use, hours of television and video viewing, participation in organized sports, non organized sports and lessons (Appendix C).

Children were asked to complete questionnaires after each work station to identify any concerns they felt during the task. Descriptive statistics were calculated. Data will be presented in graphic form.
CHAPTER 4

RESULTS AND DISCUSSION

The results and discussion in this Chapter are broken down into three main sections: segment angle analysis, joint angle analysis and subjective analysis. The discussion within this Chapter 4 is devoted to explaining the differences in children’s posture at each workstation and the inter-relationship between different segments of the body. In Chapter 5, these data will be discussed as they relate to the scientific literature. Only data where there are significant differences between AAW and CAW will be discussed in detail below.

Most of the objective data are presented in graphic and tabular form to aid with the comparison between the means of the participants at the AAW and CAW. Standard error of the means (SEM) are presented on each graph to describe the uncertainty of how the sample mean represents the population mean. The SEM seemed more appropriate than graphing the standard deviations (SD) because participants are being compared to themselves across workstations. It is less important to compare the variability between participants in the sample.

Based on screening the postural data, two participants’ data were removed due to equipment or software malfunction. This left 6 girls’ and 1 boy’s data in the sample. However, for subjective analysis, all of the participants were analyzed.
4.1 Segment Angle Analysis

4.1.1 Hand Segment Angles

The hand segment angle data revealed some differences between the AAW and CAW (Figure 8) about the three axes of rotation with only the mean flexion and extension segment angle being significant (p=0.01). Each of the segment angles will be presented below along with a feasible explanation for these results.

a) Supination/Pronation: The hand segment angle for supination/pronation showed a mean of 40 deg. of pronation at the CAW vs. 61 deg. in the AAW. While not statistically significant, it is believed that the use of the smaller size mouse may reduce the pronation angle in the hand at the CAW. The hand segment has very little motion at the wrist joint about the longitudinal axes. However, some motion does exist. It was thought that the hand sensor may be picking up some pronation and supination from the elbow joint.

b) Flexion/Extension: The hand segment angle data for flexion/extension was statistically different (p=0.01) for AAW vs. CAW. At the AAW, the mean hand segment angle was 52 deg. in extension in contrast to the CAW at 36 deg. in extension. It was hypothesized that there would be a greater extended angle of the hand while resting on the larger size mouse at the AAW.

c) Radial/Ulnar Deviation: The mean radial/ulnar deviation segment angle was not significantly different between the two workstations but did show the hand in ulnar deviation.
Figure 8. The extension segment angle of the hand was significant ($p=0.01$) at the AAW.

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Pronation (°)</th>
<th>Extension (°)</th>
<th>Ulnar Deviation (°)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult-Adjusted</td>
<td>-61.14</td>
<td>-52.47</td>
<td>-115.03</td>
<td></td>
</tr>
<tr>
<td>Child-Adjusted</td>
<td>-40.90</td>
<td>-36.76</td>
<td>-103.85</td>
<td></td>
</tr>
<tr>
<td>T-Test (2 tail)</td>
<td>0.14</td>
<td>0.01</td>
<td>0.28</td>
<td>$p&lt;0.05$</td>
</tr>
</tbody>
</table>
4.1.2 Forearm Segment Angles

The mean forearm segment angles were significantly differently between the AAW and CAW for all angles (Figure 9). The forearm assumed a position of pronation, abduction and flexion.

a) Supination/Pronation: The forearm mean segment angle was significantly different between the AAW and CAW with 23.2 deg. pronation at the AAW and 4.2 deg. pronation at the CAW (p=0.02). These results are in the same direction as the postures of the hand segment and should be combined when examining their effect on the wrist joint angle.

b) Abduction/Adduction: The abduction/adduction mean segment angles were 28.8 deg. abduction at the AAW vs. 6.40 deg. abduction at the CAW with significance of p=0.001. The forearm was held in an abducted position in order to reach the mouse and in order to position the hand lateral to the larger size keyboard.

c) Flexion/Extension: The flexion/extension mean segment angle was 105.4 deg. extension at the AAW vs. 78.4 deg. extension at the CAW with significance of p=0.001. The forearm made a significant contribution to the participant’s posture in order to accommodate for the different workstations. For example, at the AAW, participants either raised the forearm to reach the mouse, or abducted their arm so that the forearm was in a horizontal position. In summary, the forearm, in order to place the hand on the mouse at the AAW, was pronated, abducted, and
flexed to a greater degree that at the CAW. This positioning complements the hand position results shown at both of the workstations.

Figure 9. Forearm segment angles were significantly greater in all angles for the AAW.

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Pronation (°)</th>
<th>Abduction (°)</th>
<th>Flexion (°)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult-Adjusted</td>
<td>-23.20</td>
<td>28.81</td>
<td>105.41</td>
<td></td>
</tr>
<tr>
<td>Child-Adjusted</td>
<td>-4.18</td>
<td>6.40</td>
<td>78.37</td>
<td></td>
</tr>
<tr>
<td>T-Test (2 tail)</td>
<td>0.02</td>
<td>0.001</td>
<td>0.001</td>
<td>p&lt;0.05</td>
</tr>
</tbody>
</table>
4.1.3 Arm Segment Angles

All arm segment angles were significantly differently between AAW and CAW for all angles (Figure 10).

a) **Internal/External Rotation:** The arm segment was significantly rotated internally by an average of 33.3 deg. at the AAW but only 7.4 deg. at the CAW (p=0.01). Several participants abducted and rotated their arm so that it rested on the workstation. This would account for the large difference in internal rotation between workstations.

b) **Abduction/Adduction:** Similar to rotation, the mean values for arm abduction were significantly higher (27.7 deg) at the AAW than at the CAW (13.1 deg.) (p=0.01). This result supports the observation that some participants placed their elbow and forearm on the table while using the mouse.

c) **Flexion/Extension:** Similar to the previous arm angles, the AAW resulted in participants significantly flexing their arm segment by an average of 40.2 deg. in comparison to 11.5 deg. at the CAW (p=0.01). These data support the theory that the arm segment was rotated about all three axes to accomplish the task of placing their forearm on the desk while using the mouse. As stated earlier, not all participants positioned their arms in the same manner.
Figure 10. Arm segment angles were significantly greater in all mean angles for the AAW.

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Internal Rotation (°)</th>
<th>Abduction (°)</th>
<th>Flexion (°)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult-Adjusted</td>
<td>33.34</td>
<td>27.72</td>
<td>40.23</td>
<td></td>
</tr>
<tr>
<td>Child-Adjusted</td>
<td>7.76</td>
<td>13.12</td>
<td>11.55</td>
<td></td>
</tr>
<tr>
<td>T-Test (2 tail)</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>p&lt;0.05</td>
</tr>
</tbody>
</table>

4.2 Relative Angle Analysis

4.2.1 Wrist Joint Angles

The wrist mean joint angles showed significant difference in extension/flexion (p=0.001) and radial/ulnar deviation (p=0.02). There was no significant difference in the supination/pronation joint angles (Figure 11).

a) **Supination/Pronation**: As can be seen from the figure below, the wrist did not experience any difference in supination between the AAW and the CAW. As mentioned in Section 4.2, the wrist does have some mobility in axial rotation.
but it is limited. The motion identified in the wrist is probably coming from the elbow supination.

![Wrist Joint Angles](image)

**Figure 11.** The wrist showed more extension at the CAW than at the AAW and more ulnar deviation at the AAW.

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Supination (°)</th>
<th>Extension (°)</th>
<th>Ulnar Deviation (°)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult-Adjusted</td>
<td>32.22</td>
<td>-7.11</td>
<td>-11.40</td>
<td></td>
</tr>
<tr>
<td>Child-Adjusted</td>
<td>31.02</td>
<td>-32.48</td>
<td>-0.52</td>
<td></td>
</tr>
<tr>
<td>T-Test (2 tail)</td>
<td>0.84</td>
<td>0.001</td>
<td>0.02</td>
<td>p&lt;0.05</td>
</tr>
</tbody>
</table>

b) **Extension/Flexion:** The wrist showed more extension at the CAW (32.5 deg.) than at the AAW (7.1 deg.) (p=0.001). One possible reason for this difference was an anthropometric mismatch that required them to use different postures to complete the task. The participants appeared to use two strategies to reach the mouse at the AAW (Figure 12). The first of these was the position of elevating
the upper limb by abducting the shoulder and resting the forearm on the desk. This strategy allowed the wrist to remain relatively neutral. The second strategy involved holding the arm closer to the side and flexing the wrist. This strategy caused the wrist to be in a more flexed posture. Both of these strategies will allow the child to reach the desk surface.

Figure 12. Strategies used to keep the wrist straight at the adult-adjusted workstation by: A) resting the forearm on the table or B) bringing the mouse closer to the edge of the table.

c) Radial/Ulnar Deviation: A significant difference (p=0.02) was found for the wrist angle. On average, the wrist was in a neutral posture on the CAW but demonstrated ulnar deviation at the AAW (11.4 deg) (Figure 13). Jensen et al. (1998) cited repetitive movements, static postures (ulnar deviation and extended wrist) and static muscular activation patterns as risk factors for MSD.
Figure 13. Ulnar deviation of the wrist was (A) minimal in a CAW but (B) could be exaggerated in some children in the AAW.

4.2.2 Elbow Joint Angles

Elbow mean joint angles were not significant due to the anatomical structural of the joint. Therefore, postural adaptations were occurring at the surrounding joints of the wrist and shoulder. The flexion angles of the elbow joint averaged 58.1 deg and 62.0 deg. of flexion from the soldier standing posture (0 deg. of flexion). Typically, ergonomists recommend an elbow flexion angle of 90 deg. to 70 deg. for adults. Therefore, these children assumed a slightly less bent elbow (10 deg.) than recommended for adults. Perhaps their improved vision over adults allowed them to position their chair further from the computer screen.

4.2.3 Shoulder Joint Angles

The shoulder mean joint angles were significant in abduction/adduction (p=0.05) and flexion/extension (p=0.05). There was no difference in the external/internal mean rotation joint angles (Figure 14).

a) Internal/External Rotation: The mean angles were the comparable at both the AAW and CAW at 13.4 deg. internal rotation and 11.9 deg. internal rotation.
Figure 14. There were significant differences in shoulder joint abduction and flexion between the AAW and CAW.

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Internal Rotation (°)</th>
<th>Abduction(°)</th>
<th>Flexion(°)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child-Adjusted</td>
<td>-11.91</td>
<td>0.44</td>
<td>8.04</td>
<td></td>
</tr>
<tr>
<td>T-Test (2 tail)</td>
<td>0.76</td>
<td>0.05</td>
<td>0.05</td>
<td>p&lt;0.05</td>
</tr>
</tbody>
</table>

b) Abduction/Adduction: The shoulder showed significantly more abduction at the AAW (14.3 deg.) vs. at the CAW (0.4 deg.) (p=0.05). This increased shoulder abduction angle at the AAW supports the observation of the strategies that the participants used to reach the mouse on the desk surface (Figure 15). As previously mentioned this shoulder posture has been identified as a risk factor for MSD and is of concern for all of the aforementioned reasons.
Figure 15. At the AAW, children either (A) kept their shoulder close to their body or (B) abducted their shoulder and rested their elbow on the desk.

c) **Flexion/Extension**: The shoulder also showed more flexion at the AAW (19.6 deg) vs. at the CAW (8.0 deg.) (p=0.05). Figure 16 is a comparison one child’s arm flexion angles under AAW and CAW conditions. Each child had a unique method of adapting to the AAW but, regardless of this fact, shoulder flexion angles were slightly larger for AAW than CAW.
4.3 Spinal Joint Angles

Although none of the spinal joint angles were significantly different between the AAW and CAW, results will be presented below in order to provide baseline data for future research studies with children. Rather than present the data based on each joint (neck, thoracic and lumbar) in the three orientations (lateral bending, flexion/extension and rotation), it will be presented across joints so that a complete picture of spinal postures can be seen more easily.

4.3.1 Spinal Lateral Bending Joint Angles

Neck, thoracic and lumbar mean lateral bending curves were compared across AAW vs. CAW conditions with no significantly different results (Figure 17).

a) Neck Lateral Bending: There was a small amount of lateral bend in opposite directions (AAW to the left side by 3.4 deg and CAW to the right side by 3.3 deg.). This 6.0 deg. difference was not significant and therefore no pattern was shown. However, one might theorize that children and adults prefer to keep their heads level with the computer screen. Therefore, the neck, which has the greatest range of spinal motion, is the most
likely joint to accommodate for other postures that may be off-line below. For example, if a person has scoliosis or sat awkwardly in the chair, accommodations would likely be made in the cervical region. Further research is needed to confirm this theory.

![Spinal Lateral Bending Joint Angles](image)

**Figure 17.** Spinal lateral bending, while not significant, was greater in the thoracic spine at the AAW due to the postural adaptation of the shoulder.

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Neck Lat Bend</th>
<th>Thoracic Lat Bend</th>
<th>Lumbar Lat Bend</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult-Adjusted</td>
<td>-3.44</td>
<td>8.41</td>
<td>-1.90</td>
<td></td>
</tr>
<tr>
<td>Child-Adjusted</td>
<td>3.34</td>
<td>-0.90</td>
<td>1.32</td>
<td></td>
</tr>
<tr>
<td>T-Test (2 tail)</td>
<td>0.11</td>
<td>0.17</td>
<td>0.41</td>
<td>p&lt;0.05</td>
</tr>
</tbody>
</table>

b) **Thoracic Lateral Bending:** Patterns were observed between the work-stations but they were not statistically significant. One might hypothesize that abduction and forward flexion of the right shoulder and the associated scapula-humeral
movement could result in a slight lateral bend of the thoracic spine towards the right. However, further research using a larger sample size would be needed to confirm this theory.

c) **Lumbar Lateral Bending**: These results were not statistically significant with very minor differences between workstations. It is doubtful that there would be any differences since the lumbar spine is closest to the base of support on a symmetric chair seat.

### 4.3.2 Spinal Flexion/Extension Joint Angles

The neck, thoracic and lumbar flexion/extension mean joint angles were not significantly different between the AAW and the CAW (Figure 18).

a) **Neck Flexion/Extension**: Although there were no significant differences between the extension angles at the AAW (10.7 deg.) and the CAW (1.7 deg.), one might hypothesize that any spinal accommodation would occur at the neck because: i) it is the uppermost region of the spine, ii) allows the greatest range of motion, and iii) allows the head to remain level to view the screen. More participants would be needed to confirm this hypothesis.

b) **Thoracic Flexion/Extension**: The thoracic joint angle at the AAW was 6.5 deg. vs. 12.9 deg. at the CAW in flexion with no significant differences.

c) **Lumbar Flexion/Extension**: The lumbar angle at the AAW was 16.5 deg. vs. 17.6 deg. at the CAW in flexion. Therefore there were no significant differences between conditions.
Figure 18. Neck extension was greater in the AAW while there was greater thoracic flexion at the CAW, although both were not significant.

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Neck Extension</th>
<th>Thoracic Flexion</th>
<th>Lumbar Flexion</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult-Adjusted</td>
<td>-10.74</td>
<td>6.53</td>
<td>16.51</td>
<td></td>
</tr>
<tr>
<td>Child-Adjusted</td>
<td>-1.70</td>
<td>12.90</td>
<td>17.61</td>
<td></td>
</tr>
<tr>
<td>T-Test (2 tail)</td>
<td>0.13</td>
<td>0.36</td>
<td>0.82</td>
<td>p&lt;0.05</td>
</tr>
</tbody>
</table>
4.3.3 Spinal Rotation Joint Angles

The neck, thoracic and lumbar mean rotation angles were not significantly different although there was more rotation at the neck than the other regions of the spine (Figure 19). This finding is logical in that the neck is designed to rotate more easily and is the uppermost segment to adjust the head and line of sight to focus on the keyboard.

![Spinal Rotation Joint Angles](Figure 19)

Figure 19. Rotation angles were not significant throughout the spinal curves. There was more movement at the neck joints than in the thoracic and lumbar areas across conditions.

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Neck Rotation</th>
<th>Thoracic Rotation</th>
<th>Lumbar Rotation</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult-Adjusted</td>
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<td></td>
</tr>
<tr>
<td>Child-Adjusted</td>
<td>2.99</td>
<td>-3.10</td>
<td>1.01</td>
<td></td>
</tr>
<tr>
<td>T-Test (2 tail)</td>
<td>0.71</td>
<td>0.68</td>
<td>0.28</td>
<td>p&lt;0.05</td>
</tr>
</tbody>
</table>
4.4 Subjective Data Results

4.4.1 National Longitudinal Survey of Children and Youth.

Results of the 2002/03 National Longitudinal Survey of Children and Youth (NLSCY) are in Table 1. Participants’ use of computers was determined through 11 questions on computer use and physical activity and was completed manually by the parent/guardian before data collection began with the participant. Results of the NLSCY showed that all of the participants used computers at home and school at 80% and 100% respectively. They reported that use of the computer at home centred on both educational and recreational purposes. The hours of usage at home ranged from occasional to 30 minutes per day. All of the participants reported taking part in organized and non-organized sports. Non-sport activities, such as instruction in music or art, were reported by all of the participants. Television and/or video watching were reported by all of the participants as well. The time spent television or video watching per day ranged from 30 minutes to 1.5 hours with an average of 0.8 hours (or 48 minutes).
Table 1. Frequency Analysis of National Longitudinal Survey of Children and Youth.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participation in Organized Sports</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most Days</td>
<td>1</td>
<td>11.1</td>
</tr>
<tr>
<td>A Few Times a Week</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>About Once a Week</td>
<td>6</td>
<td>66.7</td>
</tr>
<tr>
<td>About Once a Month</td>
<td>1</td>
<td>11.1</td>
</tr>
<tr>
<td>Almost Never</td>
<td>1</td>
<td>11.1</td>
</tr>
<tr>
<td>Participation in Organized Physical Activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most Days</td>
<td>1</td>
<td>11.1</td>
</tr>
<tr>
<td>A Few Times a Week</td>
<td>2</td>
<td>22.2</td>
</tr>
<tr>
<td>About Once a Week</td>
<td>3</td>
<td>33.3</td>
</tr>
<tr>
<td>About Once a Month</td>
<td>2</td>
<td>22.2</td>
</tr>
<tr>
<td>Almost Never</td>
<td>1</td>
<td>11.1</td>
</tr>
<tr>
<td>Participation in Unorganized Sport/Physical Activity</td>
<td>6</td>
<td>66.7</td>
</tr>
<tr>
<td>Most Days</td>
<td>3</td>
<td>33.3</td>
</tr>
<tr>
<td>A Few Times a Week</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>About Once a Week</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>About Once a Month</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Almost Never</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time in Physical Activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 to 15 minutes</td>
<td>0</td>
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<td>Participation in Non Sport Activities</td>
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<td>About Once a Month</td>
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<tr>
<td>Almost Never</td>
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4.4.2 Visual Analogue Scale (VAS)

The Visual Analogue Scale (VAS) was used with a 10 point scale that had anchors of 0 for happy and 10 for very sad and crying when asked the question “What is your pain level”? Participants were asked to complete the VAS before and after their 20 minute session on each computer workstation. The raw data are available in Appendix I (Table 3). The level of pain scores was very low with two participants reporting pain scores of 1 before the AAW but six participants reporting pain scores of 1 after the AAW. The CAW data were somewhat contrary to expectations as the number of participants reporting a pain score of 1 changed from four to two participants after the session. One would not expect the pain score to be very large for tasks requiring such a small effort. Nonetheless, six of nine participants did identify a pain score of 1 after working for 20 minutes on the AAW. The Wilcoxon Matched-Pairs Signed Ranks Test was performed on these data with no significance. The AAW VAS was $p<0.0125$ and the CAW VAS was $p<0.5$.

![VAS Average Scores for Pain](image)

Figure 20. A summary graphic of the mean pain scores on a VAS scale before and after each condition.
4.4.3 Children’s Rate of Perceived Exertion (PCert)

The PCert is a 10 point Likert scale that is used to measure rate of perceived exertion by the participant and was administered after each condition. Raw data are available in Appendix I (Table 4). The individual scores ranged from 1 to 5 after the AAW and were 1 to 4 after the CAW with all children indicating at least some form of perceived exertion. The mean PCert scores were 3 and 2.33. The Wilcoxon Matched-Pairs Signed Ranks Test was performed on these data with no significance at p<.125. Interestingly, all children scores were either the same or went down when playing at the CAW.

![Mean PCert Scores after 20 minutes]

Figure 21. A comparison of mean PCert scores after 20 minutes of computing on AAW vs. CAW
CHAPTER 5

GENERAL DISCUSSION

In order to quantify the postural changes that children were making while playing at computer workstations, a laboratory methodology was chosen in order to simulate a home or school computer workstation environment. Psihogios et al. (2001) addressed the issue of whether monitor placement in a workplace produced postures similar to those in lab studies. Their results showed that elicited postures in a laboratory were not significantly different than in an office situation. Although not tested, an assumption was made that the same results would be true for children and that a laboratory investigation would be not be significantly different than a home or school situation.

It was also important to consider the choice of the computer game for the participants to play during data collection and the choices for safe and appropriate workstation equipment and computer equipment. Another goal was that the participants were able to feel comfortable and relaxed during testing in order to obtain accurate data. The decision was made to use double-sided tape and securing methods such as the Mefix™ tape and Surgifix™ sleeves which were not restrictive, potentially allergenic and cumbersome. It was also decided not to use other instrumentation such as EMG in order not to overwhelm the children with setup procedures. Finally, it was decided that a suitable break time would be provided between conditions with a refreshment and snack due to their young age. These considerations were important in providing an
environment where the participants could “play the computer game as if they were at home and to move around according to how they would behave at home”.

One of the concerns with measuring posture is that posture is not a static event. Thus, it is important to know if an average of segment angles and joint angles can be used to represent a 20 minute sampling period. Ortiz et al (1997) performed a repeated measures study of postural variables between and within computer users and they found that variability was significantly greater between users than within users. They concluded that a single measure of posture with repeated measures would improve power to detect posture effects (Ortiz, Marcus, Gerr, Jones, & Cohen, 1997). For this study the postural data were quasi-dynamic in that 2 samples were taken every second for a total time of 20 minutes. Although not reported in this study, it is possible to examine postural changes over time to confirm the results of the Ortiz et al (1997) study. This would allow researchers to determine how long children stayed in a mean posture before making a major body shift. Based on visual inspections, body shifts of this nature were observed within the data set but there were only none, one or two body shifts across the 20 minute data sample. Further research is needed to analyze these results.

The purpose of this study was to determine what postural adaptations children were making while playing at two computer workstations to see if posture was affected by the design of the workstation and the design of the computer equipment. Specific displacements and postural segmental and joint angles were measured and results from the AAW and CAW were analyzed. Results supported our hypothesis that: 1) children’s
postures when working at an adult’s workstation did not follow guidelines for computer workstations established by Occupational Safety and Health Administration (OSHA), while postures working at the children’s workstation do meet these guidelines (Appendix J, Table 5) and 2) children reported greater discomfort while working at an adult workstation.

Segmental angle and displacement results showed an adaptive pattern that enabled the participants to reach the mouse at an adult workstation in order to play the computer game. The participants used a postural combination of shoulder abduction and flexion to position their hand to rest on the mouse. This was in contrast to the CAW where the shoulder remained in a relatively neutral position and there was negligible abduction and minimal flexion of the shoulder. The postural adaptive sequence of shoulder abduction and flexion, as seen in the displacement and segmental joint analysis, was also confirmed in the joint angle data.

The AAW strategy of shoulder elevation, abduction and flexion produced three patterns for the placement of the forearm. They were: 1) hand on the mouse that was located on the front portion of the desk surface with the forearm resting on the front edge of the desk (see Figure 12b), 2) hand on the mouse which was located midline on the desk with the arm resting on top of the desk surface (see Figure 15b) and 3) forearm and arm held without support in the air with the hand only on the mouse (see Figure 16a).

All of these strategies at the AAW are of concern. It is well documented in the literature that sustained awkward postures are a predictor for MSD (Gillespie, 2002;
IWH, 2005). The shoulder, arm, forearm and wrist posture shown by the participants at the AAW demonstrated a number of sustained and awkward postures. The muscular effort required to hold the limbs in these positions for a sustained period of time is of concern. The stress and strain on other supporting structures such as the tendons and ligaments is also of concern. The mechanism of injury, as noted by the IWH (2005), of mechanical strain resulting in long term tissue damage would be possible with these strategies.

However, it is of concern that, when playing/working at the CAW, the wrist mean joint angle was 32.5 deg. of extension. This posture can be explained by the fact that the participant assumed a position wherein the forearm rested on the arm rest or was held in a neutral position. This positioning resulted in the hand resting on the mouse and going into extension as it cupped the mouse (see Figure 13a). This posture is not the recommended neutral posture of the wrist joint but does reflect what is reported in the literature by Gerr (2000) where 41% of the participants worked in non neutral wrist postures. A number of studies have examined wrist position as a predictor for MSD. Liu et al. (2003) found that computer workers who kept their wrists extended by more than 20 degrees were at greater risk of CTS. This wrist extension posture is of concern and the fact that it occurred at the ergonomically-adjusted workstation and with a child size mouse increases this concern and demonstrates the challenges of preventing MSD.

Another significant finding was the position of increased internal rotation of the shoulder combined with increased shoulder elevation, abduction and flexion at the AAW.
The clinical implication for the shoulder in this position is the potential for damage resulting in impingement syndrome. This could develop as a result of both long and short term exposure. At the CAW, there was less internal rotation of the shoulder that decreases the risk for impingement.

A further risk factor evident at the AAW in both the segment and joint angles was a wrist posture of increased ulnar deviation. This has been well-documented in the literature as one of the risk factors for MSD (Jensen et al., 1998; Fagarasanu et al., 2004). The position of ulnar deviation has been associated with CTS. In a survey of 30,000 adult workers affected by CTS, there was a loss of ~ 25 works days with incidence rates of CTS estimated between 0.1 % to 10% (Patterson & Simmons, 2002). In a children’s questionnaire survey of 212 students across grades 1-12, (Burke & Peper, 2002) found that many students had increased physical discomfort related to computer use with 30% reporting wrist pain. For those children who choose a strategy of exaggerated ulnar deviation, as well as wrist extension, there may be an increased risk of MSD in adulthood.

Spinal posture data were not significantly different between the two workstations, however, results did show adaptive responses to the AAW, especially in the neck in terms of joint angles and head poke. It is noteworthy that there were no statistical differences in the lumbar flexion, lateral bending or rotation angles. The lumbar spine in the sitting posture does not contribute to postural adaptations to reach the mouse in order to play or work on the computer. These adaptations would appear to happen primarily through the
shoulder and upper limb. This is confirmed in injury data wherein the increase for occupational MSD has been in the upper extremities and not in the low back (IWH, 2005).

The potential for injury in the low back would appear to come from the discal loading and the strain on the supporting tendon and viscoelastic tissues which is found in prolonged sitting postures (Shin, Shu, Li, Jiang, & Mirka, 2004). Spinal flexion has been identified as a risk factor in the postural patterns that produce pain (Murphy et al., 2004). It has also been identified that forward bending had the highest disc loading (Kayis & Hoang, 1999). Murphy et al. (2004) found an association between flexed postures and low back pain when looking at sitting postures of 66 children aged 11-14 years. Therefore, it should be noted that both lumbar and thoracic spinal flexion occurred at the AAW and the CAW. However, the effect of the different chair and workstation designs on the lumbar spine were not significant in this study.

Neck extension has also been identified as a risk factor for MSD injuries and was demonstrated to some degree at the AAW. It is interesting to note from the Black et al. (1996) study that, if the lumbar spine moved into extension, there was a corresponding movement of cervical spine flexion and if the lumbar spine flexed the cervical spine extended. There was, however, variation in whether the cervical changes occurred in the upper or lower cervical region (Black, McClure, & Polansky, 1996). Further research with a larger sample size is needed to corroborate their findings in children.
A further comment on the resultant spinal curves should be made regarding the development of spinal curves, both kyphotic and lordotic as well as scoliotic. The right shoulder adaptive posture increases the potential for compensatory spinal curves both in flexion and lateral bending (Nissinen et al., 2000). The forward flexion also increases the risk for kyphotic curves. Both of these have been identified as predictors for back pain and with the confirmation now that childhood incidence predicts adult incidence (Knusel & Jelk, 1994; Smith et al., 2003), it is imperative that efforts be made to prevent early development of spinal curves (Gerr et al., 2004). It is important to remember that spinal curves develop much earlier than parents and educators are aware at ages 12 to 14 years and thus posture is an important component of long term preventative measures to prevent back pain (Nissinen et al., 2000). Posture is also recognized as a predictor for headaches, interscapular pain and neck pain (Griegel-Morris, Larson, Mueller-Klaus, & Oatis, 1992).

The role of the feet not being able to reach the floor and offer a base of support was not measured in the study but was evident by the anthropometric data and the height of the seat pans at the AAW and CAW. For example, children in this study often swung their feet or sat on one leg as they played at the AWW. This inability to use the feet to support oneself while sitting was recently reported in a study. Implications for the importance of sitting posture are raised in the study by Smith-Zuzovsky and Exner (2004). They identified a key concern in assessment of children in a study of two groups of 20 children ages 6 and 7. They found that children who were optimally positioned
performed significantly better in an In-hand Manipulation test than children who were tested in sub-optimal seating positioning of too-large standard classroom furniture. Complex hand skills, such as those involving in-hand manipulation with stabilization, appear to be more affected by the quality of the child’s seated position than are simpler, more well-established skills. They recommended that when testing children it is important to test the child in an optimal seated position to ensure accuracy of the results, especially when the test involves complex hand skills. Optimal seating was defined as furniture fitted for tabletop activities that allowed for hip flexion to 90 degrees and foot placement on the floor and the table to be at flexed elbow height. This study has implications in terms of not only performance on an assessment, it could have implications for the critical development of motor skills. The biomechanics of not being able to support oneself by the usual foot contact with the floor means that the child is not positioned well within their base of support. This has the potential to change muscle recruitment patterns in order to create stability and maintain a posture. The concept that if this base of support is compromised, other skills such as hand manipulation are also compromised is extremely important and requires research for further understanding and validation. This is especially important when one considers the combination of adult workstations and the in-hand manipulation required at a computer.

The Smith-Zuzovsky and Exner (2004) study also raises the question whether in order to complete the task required the children are recruiting different muscle patterns? If so, are these new muscle patterns able to withstand the rigors of the task and with
repeated exposure will the muscles and joints be compromised? Further, once these muscle patterns are established, can they be corrected once the base of support is available or are they a learned muscle pattern which becomes the new normal?

The final confirmation of the need for further studies lies in the PCert and VAS responses of the children. While they were not significant, the fact that the participants perceived and recorded a difference between the two workstations supports the fact that children are reporting pain and discomfort similar to adults and that this should be taken into consideration (Jacobs & Baker, 2002).

Finally, the greater issue for discussion is the potential for harm to this generation of children and youth. The long term disability statistics from the United States tell a disturbing story of injury and disability in the under 30 population (Hainsworth, 2002). The yellow flag of concern has been raised as to the long term consequences to this generation. If the population under 30 years old increasingly becomes disabled because of musculoskeletal disorders contracted during their education and before they are even employed, society will have a significant problem. The strain on the social support network will be immense as it is not equipped to provide long-term disability for the lifetime of large numbers of young people who become disabled because of musculoskeletal disorders. The financial reality of a generation of young people on disability, who have not contributed through long term employment deductions and taxes into the government funded social support network, at the same time that the baby boomers are reaching their peak health and social demands on a limited non-renewing
financial pool, should raise the level of concern and increase the focus and attention required to investigate this area of research.
CHAPTER 6

CONCLUSIONS, LIMITATIONS AND FUTURE DIRECTIONS

6.1 Conclusion

The main conclusion of this study was the confirmation in a quantitative manner that the choice of computer workstation and computer equipment designed for children is paramount in determining which postures they will assume while working or playing at a computer workstation. The choice of a child-adjusted workstation will allow children’s postures to meet current guidelines and recommendations. The reasons for this conclusion have been presented and the results of making this choice have been quantitatively documented.

6.2 Limitations

There were several limitations in this study. The first of these was the small number of participants. A larger sample size would have been preferable and would have allowed for the removal of participants’ data without affecting the statistical significance. This problem can be overcome by using the current data to conduct a power analysis sample size estimation. In this way, current significant results would have been confirmed and other variables with weaker relationships might have been uncovered.

A large number of inter-related variable were studied. As a result two-tailed paired t-tests are not the best method of data analyses because t-tests do not examine the inter-relationship between variables. For example, the posture for the arm segment is
related to the forearm and hand postures; it takes all three segments working together to place the hand on the mouse. In this study, logical arguments were used to explain these inter-relationships. However, with a larger sample size, these relationships could be examined statistically with factor analyses or regression approaches.

Another limitation is the securing of the sensor placement on the participants. While several methods were used to secure these sensors, including double-sided tape followed by Mefix™ tape and Surgifix™ sleeves, there was the potential for sensor movement. The sensors that were the most difficult to secure were the pelvic, lumbar and cervical sensors as well as the sensor on the acromion process. Although these sensors were checked regularly, small movements might have occurred due to the children’s clothing.

In order to compare the datasets, a standardized posture had to be assumed before each condition in order to define the (0,0,0) starting point for x,y,z orientations of each sensor. The software was written to allow soldier posture as the starting point to boresight the Fastrak®. But this posture may have been difficult for children to replicate between trials. If children were not in the same starting posture, this would impact the resulting angles calculated from each sensor. It might have been easier to control the boresight posture if the children had been seated such that joint angles were either at 0 deg or at 90 deg.

A further limitation might have been the movements of the participants themselves. As they were instructed to “play the computer game as if they were at home
and to move around according to how they would behave at home”, there were postures and positions that they assumed during the 40 minutes of data collection that might have moved sensors or created a greater range in the values of the data (e.g. scratching or adjusting clothing). Interestingly, the children became absorbed in the computer game so they ignored the sensors unless they were itchy or too tightly applied.

Several children who played the game moved into postures that were not being tracked by the sensors. For example, children would curl one leg under their buttocks and shift their entire body, or lean their head onto the non-instrumented left hand thus shifting their body posture. These postures confound interpretation of the data since children are very different from one another in their accommodations to the adult workstation.

6.3 Future Directions

As discussed in Chapter 1, the area of research on children and MSD is relatively new and rapidly changing. There are many future directions that the research needs to investigate. Priority should be given to preventative strategies, although this will be very challenging. This is primarily due to the financial fact that children’s workstations for the most part are already in situ at home and school. It is only by replacing these chairs and desks with new ones that have adjustable features for children’s anthropometrics, can MSD prevention become a possibility. The financial reality is such that we are only talking about future purchases since retro-fitting these pieces of furniture poses
significant challenges. Industry would be advised to investigate and design options for retro-fitting and adapting existing furniture as a viable market option.

Changing the type of computer equipment itself could also be identified as a priority, although changing one without the other may bring its own ergonomic issues. However, benefits may still be possible by implementing simple changes such as using a smaller mouse, using a smaller keyboard with no number pad and using a smaller monitor.

Prevention is always an important area for future research. It is important that the differences in child and adult musculoskeletal systems be considered and that early prevention be initiated before tissue damage and skeletal change have occurred and before adaptive muscle patterns have become normalized. More understanding of the mechanism of injury and the injury-pain cycle will contribute to this. The most effective way to implement prevention measures for children also needs to be analyzed as parental, peer and school influences all factor into behaviour change.

Longitudinal studies that incorporate measures of children’s musculoskeletal health and methods to assess them should also be undertaken. The potential costs to the health care system should these injuries and the potential for these injuries be ignored is not to be underestimated. The future workforce needs to be protected so that children are not already compromised by this known risk factor before entering tomorrow’s workplace.
A further direction for research is adding to the body of knowledge on children’s lifestyle habits that contribute to MSD and determining the significance of their role. It is obvious that improving a child’s overall physical, mental and emotional health would be an effective intervention at every level.
REFERENCES


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Appendix A Ethics Approval

November 14, 2006

Carol Murphy
Graduate Student
School of Kinesiology and Health Studies
Queen's University

GREB Ref # GPHE-031-06
Title: “Children's Postures While Playing at Computer Workstations”

Dear Ms. Murphy:

The General Research Ethics Board (GREB) has given expedited approval to your proposal entitled “Children’s Postures While Playing at Computer Workstations”. In accordance with the Tri-Council Guidelines (article D.1.6) and Senate Terms of Reference (article 0), your project has been approved for one year. At the end of each year, GREB will ask if your project has been completed and if not, what changes have occurred or will occur in the next year.

You are reminded of your obligation to advise the GREB, with a copy to your unit REB, of any adverse event(s) that occur during this approval period (details available on our webpage www.queensu.ca/vpr/greb/adverseforms.html). An adverse event includes, but is not limited to, a complaint, a change or an unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that any adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be approved by the GREB. Examples of required approvals are: changes in study procedures or implementations of new aspects into the study procedures that affect human subjects. These changes must be sent to Linda Frid at the Office of Research Services or frid@post.queensu.ca prior to implementation. Ms. Frid will seek the approval of the GREB reviewer(s) who originally assessed your application.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

Alice B. Aiken PT, PhD
School of Rehab Therapy
Member, General Research Ethics Board

AAH

C.C.: Samantha King, Chair Unit REB
Joan Stevenson, Faculty Supervisor
Angie Maitby

think Research
think Queen's

PREPARING LEADERS AND CITIZENS FOR A GLOBAL SOCIETY
Appendix B Letter of Information and Consent

Letter of Information
And Consent Form

Children’s Postures While Playing Computer Games

Dear Parent/Guardian,

I would like to invite you and your child to participate in a research study. My name is Carol Murphy and I am a Masters of Science candidate under the supervision of Dr. Joan Stevenson, Department of Kinesiology and Health Studies, Queen’s University, Kingston, Ontario. The purpose of this study is to determine the quality and quantity of children’s postural movements while playing an educational computer game for 25 minutes at: 1) an adult workstation with adult computer equipment; and, 2) a children’s workstation with children’s computer equipment. The study will take approximately two hours to complete and will require one visit to the Biomechanics Lab at Queen’s University. You will be given a parking pass for a Queen’s lot for that visit. We would like to invite you to remain with your child throughout the data acquisition.

When you come to the lab, we will ask your child for their verbal assent and outfit them with a t-shirt, shorts and socks for ease of viewing and positioning the sensors. We will then measure the height and weight of your child as well as several body lengths so that we can adjust one of the workstations properly. Positional sensors will then be attached to key anatomical landmarks using sensor wraps with velcro, two-sided tape and other medical tape as necessary. These sensors are about the size of a acorn. Sensors will be located so that three sensors are on your child’s back, three sensors are on the computer mousing arm and one sensor is on a baseball cap.

Your child will be asked to play at two computer workstations. One station will be an adult computer workstation and chair with adult computer equipment. The other station will be an adjustable children’s computer workstation where age appropriate computer equipment (i.e., mouse, keyboard, screen) and desk and chair that will be ergonomically adjusted to your child’s measurements. Your child will be encouraged to relax and have fun playing the computer game for 25 minutes. Then, your child will be asked to take a break to relax and do something else for 30 minutes before coming back to continue playing but this time on the second workstation. After the testing is complete, we will ask your child questions about their discomfort and about the amount of time they spend playing on computers and doing other activities.

There are no known risks to participation in this study other than removing the athletic tape from the skin when the study is over. We will use skin toughness and adhesive solvents to make this athletic tape removal less painful. Participation in this study is voluntary and either you can withdraw your child or your child is free to withdraw at any time without being pressured to continue. If you do withdraw, your data will be removed.

PREPARING LEADERS AND CITIZENS FOR A GLOBAL SOCIETY

124
For your participation, regardless of whether you or your child chooses to withdraw, I wish to give your child a gift of one t-shirt.

The confidentiality of you and your child will be protected at several levels. First, the videotapes and pictures will be destroyed after the postural coordinates are extracted from them. Only fellow researchers in the biomechanics lab will view these photographs. Second, no names will be connected with the digitized data as only code numbers will be used. All data will be kept in a secure computer file or secure filing cabinet.

I plan to publish our results in scientific and lay journals. Only composite research results will be published and your child will not be identified in any way. However, I am interested in small number of examples of postures children assume at each workstation. These photographs are NOT needed for data analyses. But if you and your child are willing to have photographs taken for presentation purposes, there is a place to sign that will grant me this permission. Any images taken for this purpose will have your child’s facial features blocked from view.

If you have any questions, concerns, complaints about the research procedures or research ethics, you may contact the researcher, Carol Murphy at 613-531-8594 (cam9@uleq.queensu.ca), her supervisor Dr. Joan Stevenson at 613-533-6288 or stevensj@post.queensu.ca or the Office of Research Services at 533 6000 (ext 78281) (fridl@post.queensu.ca) for the General Research Ethics Board.

What does my signature mean?

By signing below, I am indicating that:

- I have read the letter of information
- I am aware that the purpose is to study children’s posture while playing a computer game at an adult's workstation and at a children's workstation.
- I realize we (my child or I) can withdraw at any time without penalty or coercion
- I can contact any of the people in this letter if I have questions, concerns, or complaints
- I realize that my data will be kept confidential. Only if I sign a second time below will an example photos or video be taken for possible use in presentations or publications
- By signing this consent form, I do not waive my legal rights nor release the investigator(s) from their legal and professional responsibilities.

Yours Truly,

Carol Murphy
Masters Student
Signature Page (Sign two times, one copy is for you and other one for the investigator)

Name of your child: __________________________________________________________

Name of Parent/Guardian: ___________________________________________________

Signature of Parent/Guardian ___________________________ Date ______________

By signing below, I am indicating that both my child and I are willing to allow you to use a photograph for presentation or publication purposes only. I realize my child’s facial identity will be blocked from view in these images.

Signature of Parent/Guardian ___________________________ Date ______________

Parent’s Copy of Consent Form
Signature Page (Sign two times, one copy is for you and other one for the investigator)

Name of your child: ____________________________________________

Name of Parent/Guardian: ______________________________________

_________________________________________ Date
Signature of Parent/Guardian

By signing below, I am indicating that both my child and I are willing to allow you to use a photograph for presentation or publication purposes only. I realize my child's facial identity will be blocked from view in these images.

_________________________________________ Date
Signature of Parent/Guardian

Investigator's Copy of Consent Form
Appendix C National Longitudinal Survey of Children and Youth

2002/03

National Longitudinal Survey of Children and Youth 2002/03
(Adapted)

1. In the past 12 months, outside of school hours, how often has ______ taken part in sports with a coach or instructor (except dance, gymnastics or martial arts)?
   (If unable to estimate, give frequency for that season, not for any average over the year.)
   1) Most days
   2) A few times a week
   3) About once a week
   4) About once a month
   5) Almost never

2. Taken lessons or instructions in other organized physical activities with a coach or instructor such as dance, gymnastics or martial arts?
   1) Most days
   2) A few times a week
   3) About once a week
   4) About once a month
   5) Almost never

3. Taken part in unorganized sports or physical activities without a coach or instructor?
   1) Most days
   2) A few times a week
   3) About once a week
   4) About once a month
   5) Almost never

4. Thinking of the sport or physical activity that ______ does the most often, how long does ______ usually spend being active in one session? That may be any activity with or without a coach or instructor.
   1) 1 to 15 minutes
   2) 16 to 30 minutes
   3) 31 to 60 minutes
   4) More than 1 hour

5. In the past 12 months, outside of school hours, how often has ______ taken lessons or instruction in music, art or other non-sport activities?
   1) Most days
   2) A few times a week
   3) About once a week
   4) About once a month
   5) Almost never

6. Does ______ use a computer
   1) at home
   2) at school
   3) somewhere else
   4) doesn't use a computer

7. Outside of school hours, on average, how many hours a day, do you spend on a computer (playing games, including educational games, emailing, use the Internet, etc.)
   _______ (round to nearest half hour)

8. Please confirm that ______ spends _______ hours on the computer.

9. Is there a computer in your home?
   1) Yes
   2) No

10. On average, how many hours a day, do you watch TV or video?
    _______ (round to nearest half hour)

11. Please confirm that ______ watches TV or video or plays computer games for ______ hours a day

Children's Posture While Playing Computer Games

128
Appendix E Summary of Anthropometric Measurements of Participants

Table 2 Summary of Anthropometric Measurements of Participants

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Appendix F Pilot Study

Pilot Study – Testing Sensors
Appendix G Visual Analog Scale (VAS)

**WHAT IS YOUR PAIN LEVEL?**

- 0: No Pain
- 1-5: Distressing Pain
- 6-10: Unbearable Pain

**Wong-Baker FACES Pain Rating Scale**

Instructions for use: Face 0 is happy, because he/she has no pain. Face 1 hurts just a little bit. Face 2 hurts a little more. Face 3 hurts even more. Face 4 hurts a lot. Face 5 hurts as much as the patient can imagine, although they may not be crying to feel this bad. Explain to the patient that the face at the start of the scale shows someone who feels happy because he/she has no pain (happy). The face gradually shows a change in the face to show the feelings of pain. The face becomes sad because he/she has some or a lot of pain. Ask the patient to choose the face that best describes how they feel. The visual rating scale is recommended for persons age 3 and older.


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132
Appendix H PCert Scale
Appendix I VAS and PCert Results

Table 3 Results of VAS Survey

<table>
<thead>
<tr>
<th>Subject</th>
<th>Adult Before</th>
<th>Adult After</th>
<th>Child Before</th>
<th>Child Adult</th>
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<td>Subject 2</td>
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<td>Subject 5</td>
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Table 4 Results of PCert Survey

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<th>Subject</th>
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<td>Subject 3</td>
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<td>Subject 6</td>
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<td>3</td>
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<tr>
<td>Subject 10</td>
<td>4</td>
<td>1</td>
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<tr>
<td>Subject 11</td>
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### Appendix J OSHA Guidelines vs. AAW and CAW Results

#### Table 5 OSHA Guidelines vs. AAW and CAW Results

<table>
<thead>
<tr>
<th>OSHA GUIDELINES</th>
<th>CORRECT ANGLE</th>
<th>CHILD AT ADULT WORKSTATION</th>
<th>CHILD AT CHILD WORKSTATION</th>
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<tbody>
<tr>
<td>Forearms, wrists, and hands to be straight and in-line, roughly parallel to the floor (forearm at about 90 degrees to the upper arm).</td>
<td>Forearm 90°</td>
<td>Forearm 105°</td>
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<tr>
<td>Wrist and hand to be straight (not bent up/down-no flexion or extension or sideways toward the little finger--no ulnar deviation).</td>
<td>Flexion/Extension 0° Ulnar Deviation 0°</td>
<td>Wrist Extension 53° Ulnar Deviation 11°</td>
<td>×</td>
</tr>
<tr>
<td>Head is level or bent slightly forward (flexion), forward facing (no rotation) and balanced (no lateral bending). Generally it is in-line with the torso (not bent down/back-no flexion or extension).</td>
<td>Neck Extension 0° Neck Rotation 0° Neck Lateral Bending 0°</td>
<td>Neck Extension 11° Neck Rotation 5° Neck Lateral Bending Left 2°</td>
<td>×</td>
</tr>
<tr>
<td>Shoulders and upper arms to be in-line with the torso, generally perpendicular to the floor and relaxed (not elevated - abducted or stretched forward – flexed).</td>
<td>Upper Arm Internal Rotation 0° Abduction 0° Flexion 0°</td>
<td>Upper Arm Internal Rotation 33° Abduction 27° Flexion 40°</td>
<td>×</td>
</tr>
<tr>
<td>Shoulders and upper arms to be in-line with the torso, generally perpendicular to the floor and relaxed (not elevated - abducted or stretched forward - flexed).</td>
<td>Shoulder Abduction 0° Flexion 0°</td>
<td>Shoulder Abduction 14° Flexion 20°</td>
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<tr>
<td>Elbows stay in close to the body and are bent between 90 and 120 degrees.</td>
<td>Elbow Flexion 90° to 120°</td>
<td>Elbow Flexion 62°</td>
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</tr>
<tr>
<td>Upper arms and elbows to be close to the body (not extended outward - no abduction).</td>
<td>Arm Abduction 0°</td>
<td>Arm Abduction 27°</td>
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</tr>
<tr>
<td>Feet are fully supported by the floor or a footrest may be used if the desk height is not adjustable.</td>
<td>Feet Support</td>
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<td>×</td>
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<tr>
<td>Back is fully supported with appropriate lumbar support when sitting vertical or leaning back slightly. (no flexion)</td>
<td>Thoracic Flexion 0° Lumbar Flexion 0°</td>
<td>Thoracic Flexion 13° Lumbar Flexion 17°</td>
<td>×</td>
</tr>
<tr>
<td>Head, neck, and trunk to face forward (not twisted – no rotation).</td>
<td>Cervical Rotation 0° Thoracic Rotation 0°</td>
<td>Cervical Rotation 5° Thoracic Rotation 1°</td>
<td>×</td>
</tr>
<tr>
<td>Trunk to be perpendicular to floor - no flexion (may lean back into backrest but not forward).</td>
<td>Trunk Flexion 0°</td>
<td>Thoracic Flexion 13°</td>
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<tr>
<td>No 10-key keypad if the task does not require one or a separate 10-key keypad. Keyboards without keypads allow the user to place the mouse closer to the keyboard. No number pad.</td>
<td>No Number Pad</td>
<td>Number Pad</td>
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