Journal of Interpretation

Volume 25 | Issue 1 Article 4

2016

Effects of Early Exposure to Sign Language on the Biomechanics of Interpreting

Abigail Donner

Matthew Marshall
Rochester Institute of Technology, mmmeie@rit.edu

Jacqueline Mozrall

Effects of Early Exposure to Sign Language on the Biomechanics of Interpreting

Abigail Donner
Matthew Marshall
Jacqueline Mozrall
Rochester Institute of Technology

Abstract

Sign language interpreters are routinely exposed to the high physical and cognitive demands inherent to the profession. Unfortunately, many interpreters suffer from musculoskeletal disorders as a result of this exposure. There are a myriad of factors that can contribute to the development of a musculoskeletal disorder, but many of these are not under the control of the interpreter. However, individual technique is something that affects upper extremity biomechanics and is something that an interpreter can regulate. Research with musicians has demonstrated that early exposure to musical technique can lead to the development of a technique that is more biomechanically efficient than the technique used by musicians who learn later in life. By extension, a similar effect may exist among sign language interpreters based on the age at which an interpreter first gains competency in a signed language. The objective of this study was to evaluate whether interpreters who learn sign language at a young age (middle school or younger) sign differently than interpreters who did not learn sign language until after high school. An experiment was conducted in which two groups of interpreters interpreted a recorded classroom lecture. Instrumentation was used to evaluate the posture, velocity, and acceleration of the wrist. For all biomechanical variables analyzed, no statistically significant difference was observed between the interpreters who learned sign language early in life and the interpreters who learned sign language later in life.

Introduction

Musculoskeletal injury is unfortunately a major threat to the sign language interpreting profession. Sign language interpreting requires high levels of upper extremity postural deviation and repetitive motion, often at levels that exceed those observed in occupations that have traditionally been recognized as high-risk for developing musculoskeletal disorders (MSD). These physical demands occur in combination with the high cognitive demands that are inherent to translating spoken language to signed language. Due in large part to these difficult occupational demands, a significant number of interpreters have to miss work or work with pain due to the development of MSD. In addition to interfering with interpreters' careers and daily well-being, injuries place added strain on the working interpreters who continue to support the high demand society has for their service.

The demand of an interpreting assignment is influenced by a variety of task-related and environmental factors that can contribute to high levels of psychosocial stress. Additionally,

interpreting is subject to individual expression to convey the message, and interpreters develop individual signing styles that impose varying levels of physical strain on the body. One factor that has been theorized to account for individual differences in signing biomechanics is the extent to which interpreters have used sign language throughout their lives. For example, interpreters who are children or siblings of deaf adults often have exposure to sign language very early in life compared to individuals who learn as teens or young-adults. Research has demonstrated that musicians who begin playing early in life perform with greater biomechanical efficiency than musicians who learn to play later in life (Wales, 2007; Parlitz, Peschel, & Altenmuller, 1998), so a similar relationship may exist among interpreters. The objective of this study was to evaluate the biomechanical differences in interpreting style between a group of professional sign language interpreters who developed signing proficiency early in life and a group of interpreters who developed proficiency later in life.

Musculoskeletal Disorders among Sign Language Interpreters

It has been well established that sign language interpreters experience high levels of upper extremity MSD. During the 1988-1989 academic year at the National Technical Institute for the Deaf (NTID), 45% of the employed sign language interpreters were either completely disabled or had to reduce their workload due to upper extremity pain (DeCaro, Feuerstein, & Hurwitz, 1992). In the following year, 60% of the full time interpreters at NTID were diagnosed with either work-related tendonitis or nerve entrapment disorders (Feuerstein & Fitzgerald, 1992). During that same time period, a survey of the Southern California Registry of Interpreters for the Deaf found that approximately 44% of members had some type of overuse syndrome (Sanderson, 1987). Scheuerle, Guilford, & Habal (2000) surveyed 145 interpreters and found that 119 (82%) had experienced some form of disabling pain that they attributed to sign language interpreting. Most recently, Fischer & Woodcock (2012) surveyed 314 interpreters and found that 38% reported that they had been diagnosed with some form of MSD. So, despite the awareness of the issue being raised nearly 25 years ago, the prevalence of MSDs among sign language interpreters remains a serious problem within the profession.

Risk Factors of Interpreting

The physical demands of sign language interpreting are easily observed. Less salient are the cognitive and psychosocial demands that interpreters experience as they work in a wide variety of settings. Interpreters use significant cognitive resources to process spoken source material and translate it to signed language, while working in environments in which the interpreter often has very little control. Compared to many other occupations that suffer from high levels of MSDs such as manufacturing environments, research that links specific occupational factors of interpreting to injury is very limited. Fischer, Marshall, & Woodcock (2012) present a complete review of the existing evidence and concluded that better evidence is needed in order to establish MSD pathology among sign language interpreters and to translate this knowledge into effective interventions. A brief coverage of these risk factors is presented below.

Biomechanical Risk Factors

Perhaps the most obvious risk factor that interpreters experience is the repetitive motion that is inherent to signed language. Similar to manufacturing tasks that use automated assembly lines, interpreters are not fully in control of their pace of work and must keep up with the speed of the

individual whose spoken words are being interpreted (Feuerstein & Fitzgerald, 1992). As a result, high levels of repetitive motion are normal for interpreters, particularly in classroom settings. The muscles and supporting tissues of the upper extremities experience significant internal forces as a result of producing dynamic movement of the arms, hands, and fingers while signing. In a study of wrist and forearm motion of classroom interpreters, Shealy, Feuerstein, & Latko (1991) determined that during a typical 50 minute assignment, an interpreter carries out 13,600 movements or 270 movements per minute. This drastically exceeds the recommendations proposed by Marras & Shoenmarklin (1993) that an individual in a highly repetitive job should not perform more than 13,000 hand movements over an eight- hour day.

Wrist velocity and acceleration have proven to be useful metrics for differentiating low-risk and high-risk occupational tasks in manufacturing environments, and these findings can be applied to sign language interpreting. Marras & Schoenmarklin (1993) evaluated workers in an automotive assembly plant and used angular wrist velocity and acceleration to differentiate work tasks in which workers experienced high levels of MSD development from those in which MSD development was low. Qin, Marshall, Mozrall, & Marschark (2008) and Delisle, Lariviere, Imbeau, & Durand (2005) evaluated wrist velocity and acceleration for interpreters and found that during an interpreting session both the average angular velocity and acceleration of the dominant wrist joint during an interpreting task exceeded high risk thresholds for velocity and acceleration, as defined by Marras & Schoenmarklin (1993).

Along with repetitive motion, interpreters must utilize frequent awkward postural deviation of the upper extremities. The combination of repetitive motion and awkward posture has been shown to be a major contributing factor to the development of work-related MSDs across many occupations (Bernard, 1997). Normal positioning of the interpreter's body requires that they maintain a fully pronated forearm with the wrist in ulnar deviation or extension while the elbow is flexed greater than 90 degrees. This combination of postures has been linked to a higher risk of upper extremity disorders (Shealy et al, 1991). Based on data presented by Qin et al (2008), interpreting utilizes between 71-83% of the average range of wrist motion in the radial/ulnar deviation plane and between 40-53% in the flexion/extension plane when interpreting. According to a classification of upper extremity injury risk presented by Drury (1987), the levels of injury risk are "severe" and "moderate/severe," respectively, for work activity that requires these levels of wrist deviation.

Though many people use sign language for daily communication, nothing to our knowledge has been published to document the prevalence of MSD among individuals who use sign language as their primary language. It is therefore surprising to some that sign language interpreters experience such high incidence of MSD while individuals in the Deaf community seemingly do not. What may not be fully appreciated, however, is that though casual signing and interpreting may appear similar to the untrained eye, the activities are very different. Donner, Marshall, & Mozrall (2013) analyzed the biomechanical differences between interpreting and casual conversation using sign language and found that interpreters used, on average, 22% larger wrist deviations and 7% higher levels of wrist velocity when they interpreted, compared to when they used ASL in conversation. During conversation, no significant differences in wrist kinematics were observed between the Deaf students and interpreters who participated in the conversation. Just as a lecturer may use a louder voice and annunciate more clearly in a classroom setting than when she is having an informal conversation,

interpreters seem to use a larger range of wrist motion to ensure clear articulation of the source message.

Cognitive and Psychosocial

A major difference between interpreting and casual signing that may not be fully appreciated by a naïve observer is the cognitive challenge of processing spoken source material and translating it to signed language. This is difficult even under ideal circumstances, but the demands are heightened by the stressful environmental conditions in which interpreters must often perform. This includes working in front of large groups of people or in high-stakes settings, such as medical and legal where there is added pressure to translate source material flawlessly or risk the well-being of the consumers. Furthermore, environmental circumstances, such as noise or lighting can interfere with the task and add to the adversity and stress of the interpreting session.

Dean & Pollard (2001) provide a thorough discussion of the occupational demands of interpreting and use demand control theory to model why interpreters are at such a high risk for injury and burnout. Regardless of whether the demand is physical, cognitive, or psychosocial in nature, interpreters have very little control over the environment in which they work. Typically, because of the profession's code of conduct, an interpreter does not have the latitude to intervene in a way that would make the task easier. Dean & Pollard (2001) assert that the combination of high demand and low decision latitude is a major reason for the high levels of MSDs and burnout faced by the profession.

The interaction and potential confounding of physical and psychosocial stress is often difficult to ascertain. Marras, Davis, Heaney, Maronitis, & Allread (2000) conducted an experiment in which subjects performed lifting tasks under stressful and non-stressful conditions and found that most subjects experienced an increase in spinal compression and shear forces when exposed to the stressful condition. Qin et al (2008) evaluated a group of sign language interpreters who interpreted a pre-recorded lecture while being subjected to several factors meant to induce stress, including the observation of two senior interpreters during data collection. Interpreters who reported elevated levels of stress produced non-dominant wrist velocity that was 14.8% to 19.5% greater than interpreters who did not report experiencing stress. While this finding does not establish a causative relationship between the physical demands of interpreting and the psychosocial stress the interpreter experiences, it does support an association between the physical and cognitive demands of interpreting.

Individual Factors

Sign language interpreting is an inherently demanding occupation, but it also is a task that allows individual interpreters to develop their own style. As much as individual difference in interpreting style can influence how a message is expressed, so too can these differences influence the biomechanics and likelihood of injury. Feuerstein & Fitzgerald (1992) determined that interpreters experiencing pain utilized fewer rest breaks, more frequent hand/wrist deviation, and more frequent excursion outside an optimal work envelope. Anecdotally, some have theorized that interpreters who grew up signing may have developed a technique that is more biomechanically efficient than interpreters who did not. Podhorodecki & Spielholz (1993) suggested that signing at an earlier age may result in "more natural body mechanics" after conducting a survey of interpreters and Deaf individuals and finding that all the subjects who

reported upper extremity pain were "non-native" signers who did not sign at an early age. By contrast, many interpreters choose to pursue the profession as a result of personal factors that exposed them to sign language early in life. Examples of this include children of deaf adults (CODA) and siblings of deaf adults (SODA). Often, these individuals learned to use sign language very early in life compared to an individual who decides to become a sign language interpreter in high school or beyond.

This idea of developing biomechanical efficiency through the early development of physical technique has been researched among musicians. The demands of being a professional musician resemble the demands of sign language interpreting. Both involve complex arm, hand, and finger movements that have to be carried out repeatedly and at a prescribed pace or tempo. Also in common are the psychosocial demands associated with performance: the anticipation and reaction of the audience, the personal expectations and confidence in one's abilities, and the various other environmental factors that may be present. Parlitz et al (1998) examined the effects of training and expertise on the magnitude and duration of key touch force among expert and novice pianists. The expert group consisted of pianists who started playing at the average age of six and who practice for about four hours a day. Subjects in the amateur group started playing anywhere between the ages of five and 20 and practiced for less than an hour a day. In order to achieve the same tempo and loudness, amateurs applied significantly more and longer force to the keys. Expert finger force remained below 2 N while amateur force in some fingers was over 20 N. Expert mean touch duration was 0.3 seconds compared to the amateur mean touch duration of 0.5 seconds, a difference that was found to be statistically significant (Parlitz, Peschel, & Altenmuller, 1998), suggesting that amateurs develop greater biomechanical efficiency for playing the piano. In another study, Wales (2007) examined six expert and six amateur violinists as they performed a basic bowing task. The amateurs involved in the study played for at least two years and had no orchestra experience; experts had at least seven years of orchestral experience. Novice muscle activity was both higher and more irregular during all bowing activities. Less experienced violinists also had a much shorter or even nonexistent relaxation phase after a bow direction change and much lower agonist-antagonist relationship between the biceps and triceps. Both muscles were engaged the whole time for less experienced subjects, while an antagonist relationship between the biceps and triceps was observed for the expert musicians.

It is important to make clear that for the aforementioned studies of musicians that instrumentation was required in order to identify the differences in biomechanical technique. Observation alone is not likely able to detect these important differences. Similarly, with interpreting, if there are differences in technique between early- and late-learners, even a highly trained observer may not be able to detect these differences. Experienced interpreters are often used to coach novice interpreters how to avoid bad biomechanical habits, but usually these bad habits are obvious and observable to the naked eye. Due to the repetitive nature of interpreting and the duration of the task, even small differences in biomechanical exposure could have a major impact on whether an interpreter becomes injured. Unlike the aforementioned musician studies, it is inaccurate to characterize interpreters who may have been early-learners of sign language as "more expert" than interpreters who were exposed to sign language later in life. In both cases, the interpreters have received all the training necessary to earn certification as professional interpreters. However, there still may be differences in technique that are attributable to when sign language is learned. The objective of this research was to evaluate

whether interpreters who acquire ASL proficiency early in life demonstrate biomechanical technique that is different from interpreters who acquire ASL proficiency later in life.

METHODOLOGY

SUBJECTS

Sixteen professional interpreters (11 female, five male) were recruited from among the staff interpreters at Rochester Institute of Technology as well as externally through the Genesee Valley Region Registry of Interpreters for the Deaf. Two groups of eight interpreters each were created based on the age at which the individual started using ASL. "Early signers" started using ASL at any point from infancy to middle school, while "late signers" started using ASL beyond high school age. The average age of ASL introduction for the two groups was 6.1 years (SD 5.7) and 24.3 years (SD 8.3), respectively, which was a statistically significant difference ($p < .001$). All of the interpreters in the "early signer" group had either a Deaf family member or close friend for whom ASL was the primary language for communication.

Aside from age of ASL introduction, the two groups did not differ in a statistically significant way with respect to age, years of interpreting experience, or years of signing experience (non-professional). The female/male ratio for the "early signer" group was 6/2, and the female/male ratio for the "late signer" group was 5/3. Although some interpreters had experienced pain or injuries from interpreting in the past, none of the interpreters who participated in the study were experiencing pain at the time of the study. The use of human subjects in this experiment was approved by the university's Institutional Review Board.

EQUIPMENT AND DATA PROCESSING

Wrist flexion/extension (FE) and radial/ulnar deviation (RU) were collected from all subjects using biaxial electro-goniometers (SG 65, Biometrics Ltd, Gwent, UK). Data were collected at a sampling frequency of 50 Hz with a DataLINK data acquisition and data management system. All position data collected were filtered in MATLAB using a low-pass 6th Order Butterworth filter. A 5-Hz cutoff frequency was chosen based on previous studies and was used to filter out higher frequency noise (Hansson, Balogh, Ohlsson, Palsson, Rylander, & Skervfing, 1996; Qin et al., 2008). Once the position data were collected and filtered, bilateral wrist velocity and acceleration were determined from the position data through differentiation and double differentiation using three-point central difference (Hansson et al., 1996; Qin et al., 2008). Though wrist velocity and acceleration are directional, the absolute value was used for computing descriptive statistics and analyzing effects. Along with the position and kinematics of the wrist, percentage of wrist pauses while interpreting was calculated for each trial. A pause was determined to occur whenever wrist velocity was less than five degrees/second for at least 0.2 seconds. This criterion was proposed and used by Delisle, Durand, Imbeau, & Lariviere (2007) for evaluating the biomechanics of sign language interpreting.

Experimental Task

The experimental set-up resembled a typical classroom interpreting task. Each interpreter sat adjacent to a computer screen that projected the source material. For each interpreter, a Deaf student was recruited to observe the interpreting session and was seated facing the interpreter. The students only watched the lecturer and interpreter as if they were in a class. A pre-recorded lecture, titled "Communication and Conflict in Couples and Families," was used as the source material for the task. This lecture was chosen because the content was not highly technical and is a topic relatable to most people. After a short warm-up period, an audio cue in the lecture was used to start recording data at the same time for each session. No interpreter received any prior information on the lecture before arriving to participate in the study. Twenty minutes of data were collected for each interpreter.

Results

Table 1 provides descriptive statistics of the major response variables analyzed in this experiment. For wrist movement in the flexion/extension plane, interpretation of the sign is the same for both the left and right wrist. Wrist flexion is negative, and wrist extension is positive. For wrist movement in the radial/ulnar deviation plane, sign interpretation is different for the right and left wrists due to differences in sensor orientation. For the left hand, radial deviation is negative, and for the right hand radial deviation is positive. The reverse is true for ulnar deviation. Mean wrist position is also presented in Table 1, but because the average contains both positive and negative values, average wrist position is often close to zero, or neutral. For wrist velocity and acceleration, direction and sign are less important than with position, so summary statistics were computed using absolute values.

Analysis of Variance (ANOVA) was used to determine whether statistically significant differences exist between early- and late-signers, and the summary of these analyses (p-values) are presented in Table 2. No statistically significant differences between interpreter groups were observed for any of the response variables. Detailed results for each of the response variables are described in the sections that follow.

	Left Hand		Right Hand	
	Early	Late	Early	Late
5% position (°)				
Flex/Ext	-29.5 (7.6)	-29.9 (9.7)	-26.6 (11.9)	-30.8 (8.0)
Rad/Uln	-23.3 (5.1)	-18.0 (10.2)	-15.0 (6.3)	-14.0 (9.1)
Mean position (°)				
Flex/Ext	-0.19 (5.6)	-2.5 (6.8)	2.8 (10.9)	-0.9 (5.6)
Rad/Uln	-5.9 (4.5)	-0.7 (10.6)	5.4 (4.2)	4.1 (6.9)
95% position (°)				
Flex/Ext	31.5 (5.9)	28.8 (10.7)	40.4 (11.8)	35.3 (5.8)
Rad/Uln	12.4 (5.1)	15.5 (11.0)	25.2 (3.5)	21.3 (6.9)
Mean velocity (°/s)				
Flex/Ext	50.5 (8.2)	52.9 (15.6)	77.0 (13.0)	75.7 (13.9)
Rad/Uln	31.2 (3.9)	31.8 (9.0)	44.2 (4.9)	40.1 (10.2)
Mean acceleration (°/s^2)				
Flex/Ext	628 (105)	658 (194)	995 (216)	1411 (166)
Rad/Uln	392 (106)	394 (49)	520 (144)	666 (89)
Pause Percentage				
Flex/Ext	14.3 (5.8)	14.4 (4.0)	5.3 (1.7)	7.4 (4.5)
Rad/Uln	19.4 (6.8)	19.0 (4.4)	9.3 (4.2)	11.2 (5.7)

Table 1 – Summary statistics of response variables by experimental condition.

	Early versus Late	
	Left Hand	Right Hand
5% position		
Flex/Ext	0.926	0.434
Rad/Uln	0.211	0.813
Mean position		
Flex/Ext	0.476	0.421
Rad/Uln	0.479	0.664
95% position		
Flex/Ext	0.542	0.300
Rad/Uln	0.730	0.169
Mean velocity		
Flex/Ext	0.706	0.856
Rad/Uln	0.879	0.320
Mean acceleration		
Flex/Ext	0.711	0.810
Rad/Uln	0.769	0.347
Pause Percentage		
Flex/Ext	0.949	0.271
Rad/Uln	0.902	0.448

Table 2 – Summary of ANOVA statistical significance (p-values) for each response variable.

WRIST POSITION

Figure 1 presents a summary (mean ± one standard deviation) of the wrist position for both the early- and late-learner groups for both planes of motion of both wrists. The data for the early- and late-learners are noted with “E” and “L,” respectively on the graph. Figure 1 combines the 5th and 95th percentile data presented in Table 1 to show graphically the overall range of motion used by the interpreters during the interpreting session. This range is a conservative estimate of the overall range of wrist motion used during the interpreting task.

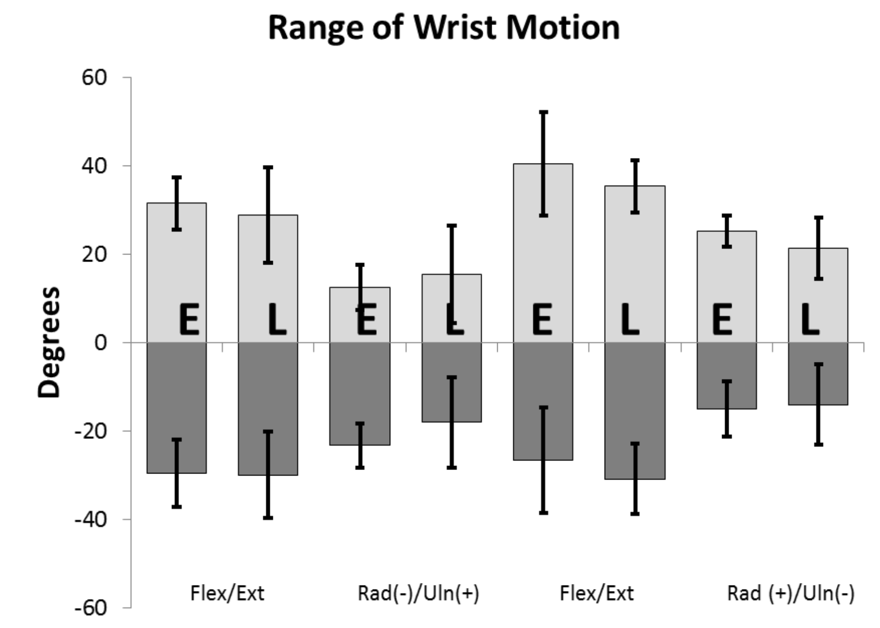

Figure 1 – Summary of range of wrist motion (5% - 95%) for early (E) and late (L) learners of sign language (mean ± one standard deviation).

As presented in both Table 1 and Figure 1, there is little difference in wrist position between the early and late groups. None of the response variables pertaining to wrist position revealed statistically significant differences between the two groups of interpreters. We have chosen to conservatively report the 5^{th} and 95^{th} percentile values for posture, rather than the extreme minimum and maximum values. Nevertheless, the overall ranges of motion observed while interpreting in this study were 67° and 40°, respectively, for flexion/extension and radial/ulnar deviation of the right hand. These ranges represent 47% and 73% of the overall ranges of wrist motion for the 50^{th} percentile female and 52% and 75% of the overall ranges of motion for the 50^{th} percentile male (Kroemer & Grandjean, 1997).

WRIST VELOCITY AND WRIST ACCELERATION

Figures 2 and 3 present a summary (mean ± one standard deviation) of the average wrist velocity and acceleration during the interpreting session. Though velocity and acceleration are directional, average values were calculated using the absolute of the measured values, since direction is assumed not to be important in evaluating the impact on injury development.

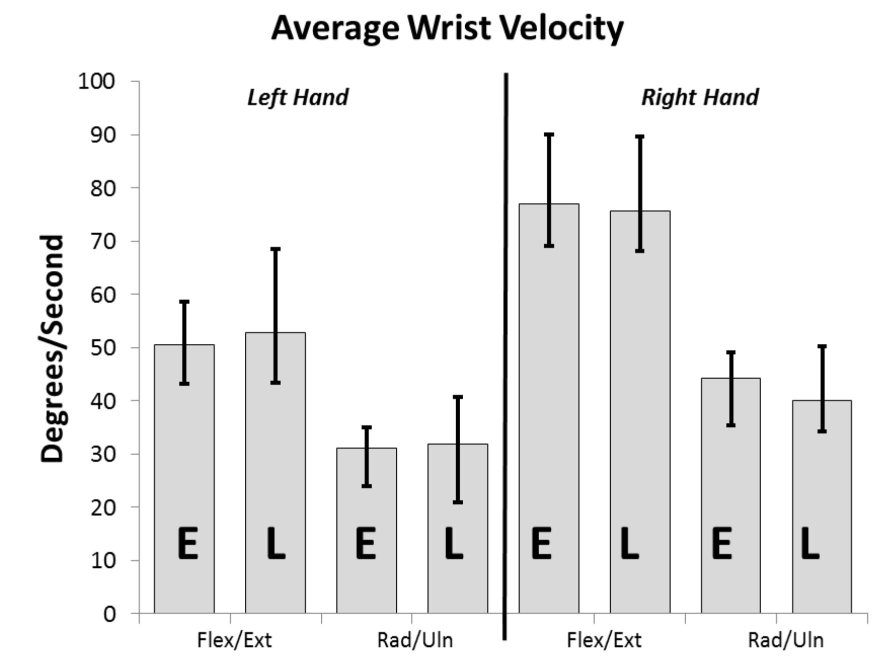

Figure 2 – Summary of average angular wrist velocity (mean ± one standard deviation) for early (E) and late (L) learners of sign language.

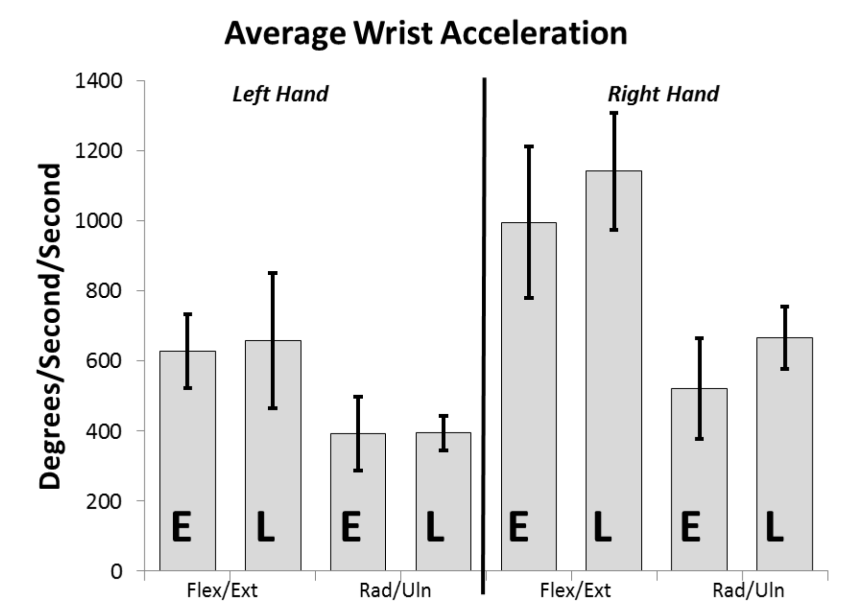

Figure 3 – Summary of angular wrist acceleration (mean ± one standard deviation) for early (E) and late (L) learners of sign language.

As was the case with wrist position, no statistically significant difference was observed for either velocity or acceleration between the early and late groups. This was true for both the right and left hands as well as for both planes of wrist movement.

PERCENT PAUSE

Figure 4 presents a summary (mean ± one standard deviation) of the percent pause measured during the interpreting sessions. Consistent with Delisle et al (2005), a pause was determined to occur whenever wrist velocity was less than give degrees/second for at least 0.2 seconds. No statistically significant difference was observed between the early and late groups. All the subjects in this experiment were right-hand dominant interpreters, so the left, non-dominant hand was paused significantly more often than the right hand.

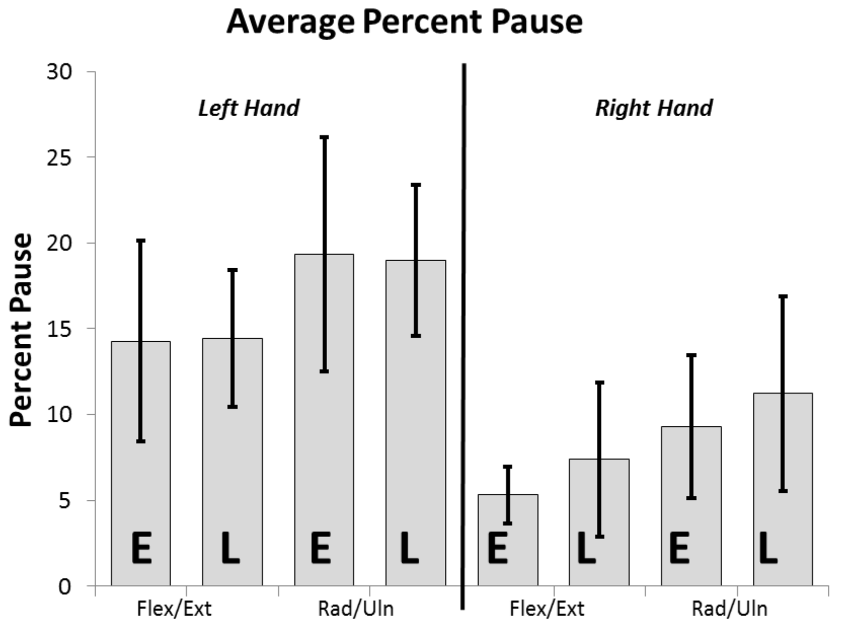

Figure 4 – Summary of the percentage of pause (mean ± one standard deviation) for early (E) and late (L) learners of sign language.

DISCUSSION

DIFFERENCE BETWEEN EARLY- AND LATE-LEARNERS OF ASL

These results provide strong evidence that for the biomechanical variables studied, no generalizable difference exists between interpreters who learn sign language early in life and those who learn it later in life. We were limited to evaluating the position and kinematics of the wrist, but interpreting affects other body segments. Most notably the elbow, shoulder, and neck/upper back are also heavily involved in interpreting. Interpreters are encouraged to contain their signing envelope to an area close to the body, which reduces the reaching required as well as the neck and shoulder strain that results when an interpreter works with frequently outstretched arms. Our analysis did not take into consideration elbow and shoulder posture, so it remains possible that the two groups of interpreters develop differences that are detectable only by evaluating these joints, such as more frequent and larger reaches outside the ideal work envelope. However, based on our observations and the convincing lack of statistical significance with all variables related to the wrist, this seems to be a remote possibility.

Our study also did not evaluate any muscle activity, which is notable since earlier studies on expert and novice musicians revealed that differences in muscular recruitment patterns exist between the two groups (Wales, 2007). Though it is inaccurate to characterize early and late

ASL learners as “novice” or “expert” interpreters, it remains possible that early learners do develop a greater muscular efficiency than late signers, even if this does not result in a difference in sign production that is either observable or measurable with goniometry. We were not able to assess muscle activity due to technical limitations of our equipment, but this is a problem for future consideration.

RISK OF DEVELOPING MUSCULOSKELETAL DISORDERS

The risk of interpreters developing a MSD has clearly been well documented and presented earlier in this paper, but our results provide additional data that indicate the occupational risk of the profession. Marras & Schoenmarklin (1993) evaluated the wrist kinematics of assemblers in the automotive industry and determined based on injury patterns, thresholds of wrist velocity and acceleration that defined “high risk” and “low risk” of developing a MSD. Figures 5 and 6 present a comparison of the average kinematic values obtained in this study with the benchmarks established by Marras and Schoenmarklin. Consistent with the findings of Qin et al (2008) and Delisle et al (2005), our results demonstrate that interpreting exceeds the high risk thresholds for wrist velocity and wrist acceleration (right hand). An important caveat to this is that the high risk thresholds are based on the work-rest cycle of an automotive worker. Compared to automotive workers, interpreters typically have much longer break periods in between or within interpreting assignments, though this is not always the case. Automotive assembly work is much more continuous and without as many longer breaks over the course of a work shift. While the profession is aware of the need to provide proper rest periods for interpreters, Figures 5 and 6 are good illustrations of the high risk of injury that interpreters face when they do not receive adequate rest while working.

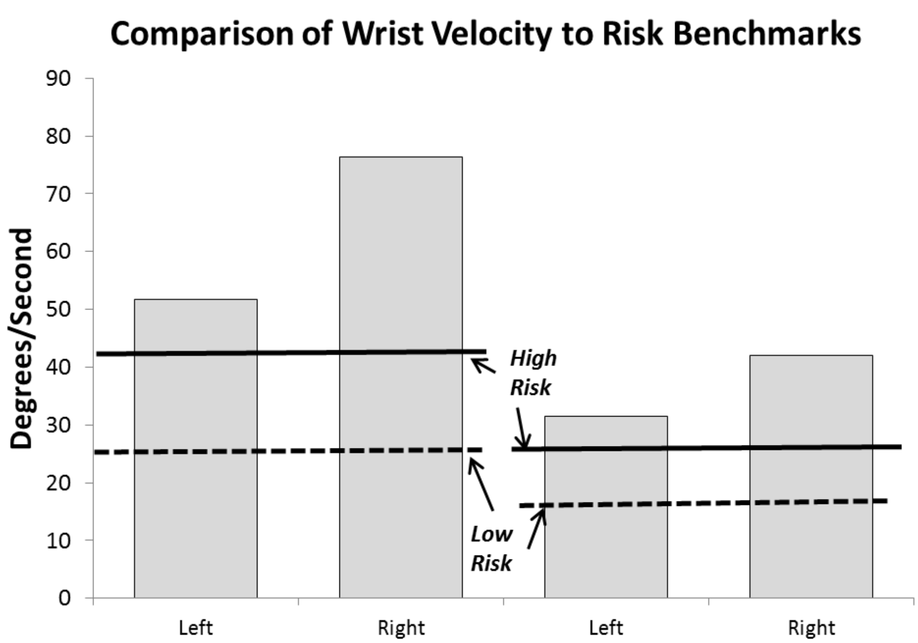

Figure 5 – Comparison of wrist velocity of sign language interpreting to low and high risk injury benchmarks established with industrial tasks.

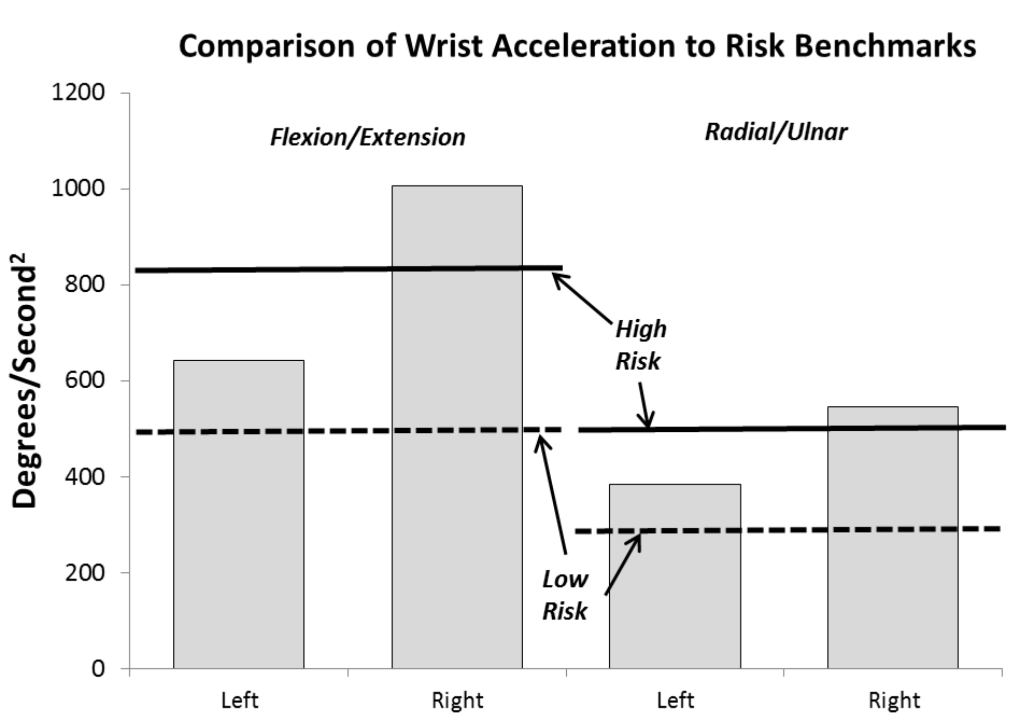

Figure 6 – Comparison of wrist acceleration of sign language interpreting to low and high risk injury benchmarks established with industrial tasks.

Another risk factor supported by these results concerns the wrist posture that interpreters experience while interpreting. From an ergonomics perspective, when a joint approaches its range of motion, the underlying tissues are stretched and undergo strain that, over time or even acutely, could lead to injury. Based on the upper extremity risk model developed by Drury (1987), the level of injury risk for the amount of wrist deviation experienced by interpreters in this study is "moderate/severe" to "severe." The wrist range of motion observed in this study (Figure 1) is consistent with the results obtained by Qin et al (2008) for a different group of interpreters who interpreted a different source material.

LIMITATIONS

Due to inherent limitations in the instrumentation used in this experiment, we only were able to investigate biomechanical variables related to the wrist. It is possible that generalizable biomechanical differences actually do exist between early- and late-learners of sign language for other biomechanical variables, including postural and kinematic differences with respect to the elbow, shoulder, and neck as well as muscle recruitment patterns within the upper extremities.

Another limitation of the experiment was the relatively small sample size (n=16). More specifically, the challenge in recruiting subjects for this study was in finding interpreters who fit our definition of early-learners. We are fortunate to have unique access to a large group of interpreters, but the subset of willing volunteers who also learned sign language early in life was smaller than we expected. Though we could have expanded the control group (late learners), we chose to retain a balanced experimental design.

References

Bernard, B.P. (Ed.). (1997). *Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back.* (No. 97-141). US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

Dean, R. K. & Pollard, R. Q. (2001). Application of demand-control theory to sign language interpreting: Implications for stress and interpreter training. *Journal of Deaf Studies and Deaf Education, 6*(1), 1-14.

DeCaro, J. J., Feuerstein, M., & Hurwitz, A. T. (1992). Cumulative trauma disorders among educational interpreters. *American Annals of the Deaf , 137*(3), 288-292.

Delisle, A., Lariviere, C., Imbeau, D. & Durand, M. (2005). Physical exposure of sign language interpreters: baseline measures and reliability analysis. *European Journal of Physiology, 94(4)*, 448-451.

Delisle, A., Durand, M.-J., Imbeau, D., & Lariviere, C. (2007). The effects of two interventions on persistent pain: A multiple single-case study among sign language interpreters. *International Journal of Industrial Ergonomics, 37*(2), 111-123.

Donner, A., Marshall, M., & Mozrall, J. (2013). Biomechanical comparison of American Sign Language interpretation and conversation. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting,* 57(1), 384-388.

Drury, C.G. (1987). A biomechanical evaluation of the repetitive motion injury potential of industrial jobs. *Seminars in Occupational Medicine, 2*(1), 41-49.

Feuerstein, M., & Fitzgerald, T. E. (1992). Biomechanical factors affecting upper extremity cumulative trauma disorders in sign language interpreters. *Journal of Occupational and Environmental Medicine, 34*(3), 257-264.

Fischer, S.L. & Woodcock, K. (2012). A cross-sectional survey of reported musculoskeletal pain, disorders, work volume, and employment situation among sign language interpreters. *International Journal of Industrial Ergonomics, 42(4)*, 335-340.

Fischer, S. L., Marshall, M. M., & Woodcock, K. (2012). Musculoskeletal disorders in sign language interpreters: A systematic review and conceptual model of musculoskeletal disorder development. *Work: A Journal of Prevention, Assessment, and Rehabilitation, 42*(2), 173-184.

Hansson, G. Å., Balogh, I., Ohlsson, K., Pålsson, B., Rylander, L. & Skervfing, S. (1996). Goniometer measurement and computer analysis of wrist angles and movements applied to occupational repetitive work. *Journal of Electromyography and Kinesiology, 6*(1), 23-35.

Kroemer, K.H.E. & Grandjean, E. (1997). *Fitting the task to the human: A textbook of occupational ergonomics.* London: Taylor & Francis.

Marras, W. S. & Schoenmarklin, R. W. (1993). Wrist motions in industry. *Ergonomics, 36*(4), 341-351.

Marras, W.S., Davis, K.G., Heaney, C.A., Maronitis, A.B., & Allread, W.G. (2000). The influence of psychosocial stress, gender, and personality on mechanical loading of the lumbar spine. *Spine, 25*(23), 3045-3054.

Parlitz, D., Peschel, T., & Altenmuller, E. (1998). Assessment of dynamic finger forces in pianists: Effects of training and expertise. *Journal of Biomechanics, 31*(11), 1063-1067.

Podhorodecki, A. D. & Spielholz, N. (1993). Electromyographic study of overuse syndromes in sign language interpreters. *Archives of Physical Medicine and Rehabilitation, 74*(3), 261-262.

Qin, J., Marshall, M., Mozrall, J., & Marshark, M. (2008). Effects of pace and stress on upper extremity kinematic responses in sign language interpreters. *Ergonomics, 51*(3), 274-289.

Sanderson, G. (1987). Overuse syndrome among sign language interpreters. *Journal of Interpretation, 4*, 73-77.

Scheuerle, J., Guilford, A. M., & Habal, M. B. (2000). Work-related cumulative trauma disorders and interpreters for the deaf. *Applied Occupational and Environmental Hygiene, 15*(5), 429-434.

Shealy, J., Feuerstein, M., & Latko, W. (1991). Biomechanical analysis of upper extremity risk in sign language interpreting. *Journal of Occupational Rehabilitation, 1*(3), 217-225.

Wales, J. (2007). *3D Movement and Muscle Activity Patterns in a Violin Bowing Task.* (Masters thesis). Brock University, St. Catharines, Ontarion, Canada.