Clinicians' Perspectives on Cross-Education in Stroke Rehabilitation

by

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Abstract

Purpose: Cross-education is a neural phenomenon where an untrained limb improves after unilateral training of the opposite homologous limb. It has been extensively studied in the healthy population and shows promise for post-stroke rehabilitation. Despite this promise, cross-education has not been adopted into clinical rehabilitation practice. Cross-education is contrary to current best practice for upper extremity post-stroke rehabilitation which is focused on training the affected limb. The objective of this study was to understand: current post-stroke upper extremity rehabilitation practice, clinician's perspectives on cross-education, and facilitators and barriers to implementation of a cross-education intervention.

Methods: An Interpretive Description framework guided this study. Twenty- two occupational therapists and 2 physiotherapists were interviewed in 4 focus groups and 1 individual interview in a rehabilitation hospital and 3 acute care hospitals. After transcription, line-by-line coding was done by 2 investigators. A third investigator, who was not part of data collection, reviewed the process and agreed on the primary categories.

Results: Cross-education is antithetical yet promising was the lone theme which was reiterated in every data collection session. The primary theme was captured in 3 descriptive categories. The therapists described working in a (1) forced-use paradigm, yet they also described how that paradigm did not meet the needs of all of their patients. They recognized this as a (2) gap in current practice. They also hypothesized that (3) cross-education used as an adjunct could be quite effective within their current practice for specific patients. The primary theme weaves between the 3 categories.

Conclusions: Therapists perceived that cross-education would be most appropriate for patients with a severely impaired upper extremity. They suggested that educational materials for clinicians, patients, and patient families would be essential to the success of cross-education in order to explain training the less affected limb. This study provides important foundational information about clinician perspectives

that will help transition cross-education into clinical stroke rehabilitation research and eventually practice.

Preface

This thesis is an original work by William Russell. This project received research ethics approval May 12th, 2015, from the University of Alberta Research Ethics Board, for the project "Clinicians' perspectives on cross-education and its utility and feasibility in acute rehabilitation" Pro00055567. The Northern Alberta Clinical Trials and Research Centre ethics approval was granted on June 10th, 2015. Covenant Health Research Operational/Administrative Approval was granted on December 4th, 2015.

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Table of Contents

Clinicians' Perspectives on Cross-Education in Stroke Rehabilitation i

Abstract ii

Preface iv

Acknowledgements v

List of Figures ix

Introduction 1

Literature Review 5

History of Cross-Education 5

Nomenclature Problem 6

Transferring Effects 8

Proposed Mechanisms 9

What factors influence cross-education? 11

Subject Characteristics 12

Training Parameters 13

Cross-education and participants with injury or illness 16

Cross-Education and Stroke 18

Problem Statement 21

Objectives 21

Methods 22

Methodology 22

Framework 22
Research Design 22
Recruitment 23
Sample 23
Ethics 25
Study Procedures 25
Data Analysis 25
Rigour 27
Theoretical Position 28
Methodological Coherence 28
Verification Strategies 29
Results 31
Antithetical Yet Promising 31
Forced-Use Paradigm 32
Gap in Current Practice 34
Cross-Education as an Adjunct 35
Discussion 38
Implementation of Cross-Education 39
Why would cross-education work? 39
What factors may limit the impact of cross-education? 41

How can we make cross-education work? 43

How do we make cross-education work in clinical stroke research? 45

Limitations 48

Conclusion 49

References 51

Appendix A: Focus Group Semi-Structured Interview Guide 62

List of Figures

Figure 1: Relationship of theme and categories

Introduction

If you wanted to increase the strength of your left bicep you would likely start doing left arm bicep curls with a weight. What if your left bicep was impaired due to injury or illness? Cross-education has been presented by scientists as a solution to this question.

Cross-education is a phenomenon in which there is a positive effect on the untrained contralateral limb after unilateral training of the opposite homologous limb.[1] Simply explained, cross-education is training on one side of the body and finding a positive effect on the opposite untrained side of the body. Cross-education was first described in 1894[2] and has been studied throughout the last 120 years resulting in a large literature base. Surprisingly, cross-education is not currently a rehabilitation strategy for unilateral injury or impairment.[3]

The first description of cross-education ignited a fire of research which has resulted in >100 published articles related to the phenomenon. That fire has not become a blazing bonfire, despite researchers purporting the therapeutic potential of cross-education; it has merely continued to smoulder throughout the century. There are many factors which could have potentially limited the translation from discovery to clinical research. These factors include, (1) the myriad of terms used to describe the phenomenon,[4] (2) the results of 2 meta-analyses which reported that "the effects are real but small,"[1,5] (3) lack of a clear mechanism underlying the phenomenon,[1,6] (4) the "effects" under study have been varied, and (5) unsuitable methodological designs have been used to overcome a training task easily affected by learning and placebo.[7] The literature review of this thesis will discuss these factors.

Researchers have recommended cross-education as a rehabilitation strategy for unilateral injury or impairment including fractures,[8] anterior cruciate ligament injury,[9] severe lateralization of weakness as a result of multiple sclerosis,[7] unilateral knee osteoarthritis,[10] and hemiparesis after stroke. Cross-

education and people with stroke is limited to 3 studies.[8,11,12] The 3 experimental studies on cross-education and stroke rehabilitation have shown positive results which were greater than the aforementioned meta-analyses. The evidence is slowly building towards its efficacy; however, if effectiveness within stroke rehabilitation is to be demonstrated, then research on the integration of cross-education into clinical rehabilitation is required.

Recently, more research on this phenomenon has been with a variety of clinical populations including stroke, as discussed above [7,8,13]; however, to advance the phenomenon at an expedited rate, scientists need to work as a community on the aforementioned 5 factors to ensure the knowledge is well synthesized for end users, such as policy makers, clinicians, and patients. Despite the existing areas requiring further research, potentially, understanding the counterintuitive nature of cross-education in relation to the current clinical paradigm could be the most important translation barrier for cross-education to stroke rehabilitation.

Why stroke and what does current practice look like?

Stroke is a broad term which is used to define neurological dysfunction which persists for greater than 24 hours as a result of tissue death in the central nervous system because of blood restriction.[14] Stroke is prevalent in Canada, has a high mortality rate, and is one of the most disabling diseases.[15] The Heart and Stroke Foundation of Canada reports that there are approximately 50,000 strokes every year in Canada. The Heart and Stroke Foundation of Canada also reports that there are 315,000 Canadians living with the effects of stroke and as fewer and fewer people die from stroke that number will increase, continuing to increase the demands of the rehabilitation system.

Stroke leads to disabilities related to communication, walking, and arm function – all of which can ultimately affect the ability to carry out activities of daily living such as dressing, bathing and eating. The arm is often the most affected; at 3 months post infarct only 20% have normal function in their

affected arm[16] and 65% of persons with chronic stroke have long term impairment in the upper limb.[17] Thus, rehabilitation strategies that improve arm function are vital to people with stroke.

Patients want more attention and rehabilitation provided for the arm.[18] In a qualitative study by Barker and Brauer they found that participants who had limited movement in their upper limbs, felt they had nothing to practise with their affected limb.[18] These participants also felt that much more attention was given to their legs; yet, now (3 months to 13 years post-stroke) many felt they would rather have arm function than leg function.[18] Upper limb function is more highly correlated with quality of life than mobility in patients 3 to 9 months post stroke.[19] This evidence shows that there is a need for more upper limb interventions to improve function for those patients with severely impaired arms. Function is a priority and is essential for quality of life.

Several rehabilitation interventions to improve arm function are included in the Canadian Stroke Best Practice Recommendations.[3] These guidelines aid rehabilitation specialists, such as occupational therapists and physiotherapists, in providing treatments that are based on the best evidence. Treatments are recommended with 3 different levels of evidence: A, B, and C. High level evidence based strategies (level A) to improve arm function after stroke in the acute rehabilitation stage include; Graded Repetitive Arm Supplementary Program (GRASP), Modified Constraint-Induced Movement Therapy (mCIMT), Functional Electrical Stimulation (FES), mental imagery, mirror therapy, and forms of sensory stimulation such as biofeedback or acupuncture.[3]

The effectiveness and applicability of rehabilitation interventions (such as the interventions listed above) are dependent on patient characteristics as well as the way in which the intervention is delivered. Many interventions are not possible with patients who have little or no active movement in the hemiplegic arm due to limited movement. For example, GRASP is only suitable for those with a Fugl-Meyer Assessment of Motor Recovery after Stroke (FMA) score of 10 to 57 and palpatable wrist extension (grade 1).[3] To be a candidate for mCIMT participants must have >20° active wrist extension

and >10° active finger extension on the more affected side, again restricting the type of patient that can benefit.[3] The only therapy in the Canadian Best Practice Recommendations for Stroke Care for patients with flaccid arms (Chedoke McMaster <3) is electrical stimulation but it still has to be tolerated by the patient. Therefore, cross-education should be explored as an additional therapy for patients with severely impaired or flaccid arm.

Cross-education is opposite to typical treatment for upper extremity hemiparesis after stroke and has not previously been implemented as a rehabilitation strategy for impairment after stroke despite its long history of research. It is important then to understand, as researchers, the barriers and possible facilitators of the implementation of this potential training strategy in a clinical setting. This a priori strategy aids in the justification of the investment of time and resources needed to examine efficacy and effectiveness of a new intervention. A qualitative study on the clinical perspectives on upper extremity rehabilitation and the implementation of a new intervention is required. The results from this study will help to further develop cross-education as an intervention for persons with stroke and determine how best to integrate it into the clinical realm.

Literature Review

History of Cross-Education

In 1894, at the Yale psychology lab, it was determined that improvements in an untrained limb were made after unilateral training of the homologous limb.[2] Scripture, Smith, and Brown conducted 2 unilateral training experiments, utilizing skill and strength tasks, to test changes in muscular control and muscular power. Both the skill and strength tasks were only trained with the right hand and the left was only measured pre and post training. The strength and skill of the untrained left limb increased 26% and 43% respectively. The transferring effect to the untrained limb was called cross-education. These simple experiments are considered the origin for all existing cross-education research today.

The discovery of cross-education spurred many questions. In what muscles does this effect occur? What can transfer: skill, accuracy, endurance, strength? Davis, 1898, found that the transfer effect seemed to be greatest in homologous body parts.[20] For example, the transfer from right arm to left arm was greater than from right arm to left leg. It was also determined, in 1950, that an "all-out effort" when training resulted in greater cross-education.[21]

Cross-education was discovered when very little was known about muscular control. Much of the early research in muscular control was extrapolated to cross-education because unilateral training protocols were employed. Throughout the late 1800s and early 1900s, Wissler and Richardson,[22] Walshe,[23] and Davis[24-26] made considerable contributions through discoveries in diffusion of motor impulses to associated muscle, reflexes in hemiplegia and tendon reflexes, voluntary muscle contraction, and age related changes in voluntary muscle activation respectively.

There were many limitations in early research in cross-education. This research area has spanned a large time frame (1894-present), and in that time period much has changed in our understanding of basic human physiology as well as, research methods including the quality and

availability of measurement tools. The findings of this early research were treated with great caution because of many of the flaws within the methodology, such as sampling errors (authors were often subjects), small sample sizes (≤2), training apparatuses that did not isolate the training limb, and lack of control groups which all bias the research towards rejecting the null hypothesis. Slater-Hammel, in 1950, attempted to address these concerns of methodology and still found results very similar to others' earlier work.[27]

Strength was and is the easiest variable to test the transfer magnitude but researchers have also been interested in exploring other variables whose effects may transfer. Hellebrandt et al. (1951) tested manual dexterity with a pencil and paper test. Despite shortcomings in the methodology, improvements in the untrained limb were seen in 3 of the 4 components of the test.[28] Cross-education continued to evolve with new measurement techniques such as electromyography (EMG). Gregg (1957) used EMG to assess muscle activity under training conditions. The cross-education effect (muscle activity) was seen in the triceps and biceps brachii of all participants after isotonic flexion and extension training.[29] EMG was new to research at this time and the use of EMG today is still very prominent in cross-education research.

In 1975, Shaver was the first scientist to overcome some of the previously discussed methodological concerns.[30] He used a large homogeneous sample, 100 male subjects who were all right handed, and were randomized to either experimental or non-exercising control groups. This strategy effectively proved that cross-education was a real effect and not a product of experimental procedure. Because of Shaver's rigorous methods his work was still included in recent meta-analyses and has influenced the design of subsequent work in the area of cross-education.[1,5]

Nomenclature Problem

Despite the initial nomenclature of "cross-education" used by Scripture, the phenomenon has been termed and defined in many different ways over the years.[2] Within 6 years of Scripture's discovery

of “cross-education,” the terms and definitions used in others’ research began to vary. Wissler and Richardson,[22] in 1900 introduced the term “cross-exercise”, though it is difficult to discern whether this was a new term or if it was intended to be used synonymously with “cross-education”. Slater-Hamel,[27] in 1950, used the term “bilateral effects” but reported that his research was building on the work of Davis, which was in cross-education. In 1957, a review of the literature[29] summarized the first 60 years of research and the primary term remained “cross-education”. However, the experiment described in conjunction with that review [29] was titled with the term “cross-exercise” and utilized “transfer effects” and “overflow” without defining or referencing any difference in definition. The variability of terminology and definition within the literature only continued to increase. For example, Eastridge and Rice[4] listed the following terms, “cross-transfer”, “cross-education”, “cross-training”, “cross-exercise”, “interlimb transfer”, or “intermanual transfer” all for the same experiment.

Two research teams have attempted to clarify the terminology and definition. Zhou[31] in 2000, declared that “Cross education occurs during both the learning of skills and the improvement in strength, and shows specificity to the prescribed training.” (p. 177) Carroll et al.[1] made the distinction between strength gains and all other transferable effects by stating:

> “The phenomenon whereby training one side of the body increases the strength of muscles on the other side of the body has become known as the contralateral strength training effect. The same effect is sometimes termed cross-education or cross training, although these terms have a broader use.” (p 1514)

Farthing,[32] acknowledges that cross-education has been used as a broader term but because skill transfer and strength transfer could be closely connected in their underlying mechanisms they should both be part of cross-education. The variability in terminology hinders the advancement of research in this field, and most importantly its potential clinical application to patients. Consistent use of terminology and definition improves the researcher’s ability to operationalize the definition and utilize appropriate outcome measures, improves communication between researchers, clinician, and client, and makes the body of literature easier to access and synthesize.

An unpublished critical review by Russell WH, Ezeugwu VE & Manns PJ, (2013) aimed to resolve the term and definition issues. The authors determined the term used should be "cross-education" and the definition be "an effect on the untrained contralateral limb after unilateral training of the opposite homologous limb." It was found that the "transferring effect" was incredibly varied across research studies. The review (Russell et al. 2013) found that both skill and strength have been studied. Strength was the most common effect studied but other researched effects include skill (or motor learning),[4] range of motion (ROM),[8] balance,[33] and endurance.[34,35]

Transferring Effects

Through the extensive research collected to conduct this literature review and supported by the work of the aforementioned critical review (Russell et al. 2013), we know that the vast majority of research in the field of cross-education has been conducted on strength training procedures. The literature specifically related to strength was compiled in a systematic review and meta-analysis conducted in 2004 and updated in 2006.[1,5] These reviews only used studies that: clearly randomised participants to control and experimental groups, training was conducted at a minimum of 50% of maximal strength, and enrolled participants who did not have any existing abnormal neuropathology. The 2004 review included 13 studies[5] and the update review added 3 studies.[1] The muscle groups studied (number of studies in parentheses) were knee extensors (7), elbow flexors (5), plantar flexors (2), 5th digit abductors (1), and flexor carpi ulnaris (1). The reviews concluded that strength gains in the untrained limb are not a by-product of testing procedures but a true transfer from the trained limb. The meta-analysis portion of the Munn et al. review found that there is approximately an 8% increase in the untrained limb[5] and the 3 studies used in the update were in agreement.[1]

Another outcome that has been studied in conjunction with a cross-education intervention is ROM. ROM was a secondary outcome in a RCT evaluating the clinical application of cross-education with patients who had a distal radial fracture.[8] It was found that wrist flexion/extension ROM was

significantly greater in the experimental group (100.5°±19.2°) than the control (80.2°±28.7°) at week 12 of the training program. To the authors' knowledge this was the only study to investigate the effect of cross-education on ROM. More research about the potential effects of cross-education on ROM is required as this transferring effect could have several rehabilitation implications especially in populations noted to be a risk for loss of ROM (e.g. neurological populations with increased muscle tone).

The cross-education of muscular endurance has been explored concurrently with strength training. Kannus et al. found endurance did transfer to the untrained leg[34] whereas Shields et al. found rhythmic handgrip training did not increase endurance in the untrained hand.[35] Shaver and Meyers also found that endurance was transferred to the untrained side.[36,37] These studies are older (1967[37] to 1999[35]), which suggests that re-evaluation or new research related to endurance may be warranted, particularly as it relates to clinical populations.

A variety of effects will significantly change the untrained contralateral homologous limb including skill.[4,32,38] Skills such as cranking resistive wing nuts[4] or reaching movements[38] are more typically considered skills. Farthing and colleagues theorized that skill and strength have similar cortical pathways. It was thought that by choosing a "novel or unfamiliar" strength task it would be more similar to a skill and the transfer of strength would be greater to the untrained limb than a typical strength task.[39] Farthing et al. used ulnar deviation. All 3 "skills" measured in these studies showed positive transfer from the trained limb to the untrained limb when compared to a control group. Both Criscimanga-Hemminger et al.[38] and Farthing et al.[39] found that the transfer only existed when training the dominant limb (skill and strength mechanisms and limb dominance to be discussed later).

Proposed Mechanisms

The physiological mechanisms controlling the transfer of effects from a trained limb to an untrained limb have perplexed researchers since the discovery of cross-education in 1894. To date,

there is not one prevailing answer with experimental evidence that explains cross-education. There are however, a number of plausible theories partially substantiated. There is agreement that cross-education is not facilitated by hypertrophy or changes in enzyme activity.[1,40] Farthing and team have repeatedly shown, through the use of ultrasound, that muscle hypertrophy does not occur during cross-education.[39,41-44] Multiple imaging studies have also shown that the cross-sectional area of the muscle does not change.[40,45] By ruling out these other mechanisms of strength gain, it is widely believed that cross-education is a product of neural adaptations.

Where and how cross-education is facilitated within the neural circuitry is unknown; however, there are several theories which contribute to our current understanding of the mechanisms underlying cross-education. Greater cross-education effects have been found when training with a novel task.[32,39] Because of this finding it has been theorized that motor learning contributes to mechanisms of cross-education. Learning or motor learning is often explained through a term called engrams; the physical representation of the output within the cortical circuitry.[46] These internal representations would then become available to the contralateral hemisphere.[40] The 'availability' to the other hemisphere is believed to be accessed through the corpus callosum. It is known that high-force unilateral contraction decreases the transcallosal inhibitory pathway and therefore repeated high-force repetitions may lead to a longer lasting inhibition of the inhibitory pathway facilitating the accessibility of the internal representation to the other hemisphere.[40] To further support the motor learning and transcallosal pathway hypothesis, is the supplementary motor areas high involvement in motor planning[47] and that the SMA has a greater interhemispheric connection than other homologous motor areas involved in learning.[48-50] These pieces of evidence support the involvement of motor learning in the effects of cross-education.

Farthing developed a model for the cross-education of strength in the upper limbs[32] to further explain the asymmetry of strength transfer and the similar cortical processes between strength gain and

motor learning. This model incorporates the cross-activation model (motor programs are stored in both hemispheres after unilateral acquisition) and the proficiency model (learning with the dominant hemisphere provides a "better" motor program). This combination of models leads to the hypothesis in which training the dominant side with a more complex and unfamiliar task will result in the greatest degree of transfer because it the dominant limb is stronger and better able to execute the motor plan.

The other, more predominantly studied hypothesis of cross-education mechanisms is the reorganization of the motor pathways to the contralateral side. It has been theorized that this occurs at both the cortical and spinal levels. Many authors have studied the cortical reorganization through paired-pulse transcranial magnetic stimulation (TMS).[49-59] It is known that interhemispheric inhibition (IHI) can be facilitated or inhibited by the magnitude and duration of the stimulus.[40] Hortobágyi also found that by using TMS with ballistic finger movements they could reduce the IHI at rest and upregulate the excitability of the primary motor cortex.[52]

The spinal pathways have been studied frequently. The H-reflex is often thought to contribute to cross-education through presynaptic inhibition of the Ia afferent motor neuron.[53,60] Reciprocal inhibition has also been considered as a mediator of cross-education because it has been theorized that the agonist could exhibit more force if the antagonist were inhibited. Renshaw cells could potentially mediate the antagonist inhibition but to date, experimental evidence is lacking to support Renshaw cell involvement.[40]

What factors influence cross-education?

As with any research there are many variables which influence the understanding of results and our ability to interpret and trust those results. Because cross-education is studied in humans it becomes very challenging to identify and control for the vast number of variables. Some of these factors include subject characteristics such as age, gender, limb dominance, health status and experience with the

effect under-study. Other variables are specific to the training parameters such as contraction type, voluntary or stimulated contraction, velocity, intensity, and volume.

Subject Characteristics

Gender has been investigated in 1 male/female comparison study and other single gender experiments which provide information about the effect of gender on cross-education. The study which tested the differences between males and females did not find any difference in percent change of pre and post measurements on the untrained limb.[61] Additionally, multiple studies have shown positive cross-education effects using a single gender for the experimental subjects. Two studies by Hortobágyi and colleagues, used homogenous samples (14 males, 14 females) in each experiment and found similar percent strength change in the untrained limb (20.9%[62] and 19.0%[63] respectively). This work confirms that the transfer of strength to the untrained homologous limb is not affected by gender.

The effect of age on cross-education is frequently reported as not having any impact on the transfer of an effect to the untrained limb (references are from review articles only).[31,40,64] The vast majority of cross-education research has used young healthy adults (early 20s). In the literature collected for this review it was found that approximately 9 out of 80 experimental articles examined older versus younger, or a homogenous sample of older adults. Three studies specifically considered changes in an untrained limb when comparing young and old age groups. It is problematic to compare these studies because of the different muscle groups, limbs trained, training parameters, and age group cut-points. The young category age ranges in the 3 studies were 18-25, <33, and 18-27; the old categories were 50-65, >62, and 60-78.[49,50,65] Two studies trained the dominant limb[50,65] and the other the non-dominant.[49] The results are inconclusive: Bemben and colleagues[65] as well as the most recent work by Hinder and team (2013)[49] reported no difference in the cross-education effects between the young and old age groups whereas Hinder and associates (2011)[50] found that the older group within their study did not have significant gains in the untrained hand after unilateral ballistic index finger

abduction on the dominant hand as compared to the younger group. Some of the other research with older participants is found in the limited clinical research literature. These studies examined distal radial fracture,[8] stroke,[12] and osteoarthritis.[10] All articles reported positive gains or preventative effects for the untrained limb in these older populations. These results offer confidence for future research in the application of cross-education in a likely older clinical population despite the inconclusive results of the 3 articles which directly evaluated age as a confounding variable of strength gained through cross-education.

The most recent participant characteristic to be considered in cross-education research is limb dominance. Historically, researchers working in the area of cross-education worked under the supposition that the training limb did not impact the transfer of an effect from a trained limb to an untrained limb.[66] It was not until 2005 that limb dominance was shown to have a strong influence on the magnitude of the cross-education effect.[39] Farthing and team examined directionality of cross-education by studying ulnar deviation in right-hand dominant, young healthy females. The results were striking and in complete opposition to their hypothesis; the strength in the group that trained the dominant limb increased by 39.2 ± 7.8% whereas the non-dominant training group increased by 9.3 ± 4.9%.[39] The potential confound of limb dominance needs further exploration because many authors have randomized participants to a training limb (i.e., dominant or non-dominant in equal numbers) which could create a wash-out effect and drastically alter the magnitude of the effect.

Training Parameters

Training parameters can be divided into muscle contraction type, volume of exercise (days, sets, and repetitions), intensity, and rest. These variables have not been standardized across cross-education research, thus they have not been systematically evaluated for the effects on cross-education.

Muscle contraction types are defined by the muscle length and the speed. There are 3 types of actions: concentric (shortening), eccentric (lengthening), and isometric (no change). Hortobágyi et al.

and Seger et al. both found that muscle lengthening had a greater cross-education effect for strength than concentric contractions.[62,67] The 3 types of muscular contractions are further defined by the velocity under which they are performed. The velocity can be fluctuating or constant. In our daily life, contractions always require differing velocities to meet the varying muscular demands of everyday movement. The only way to control the velocity required in a contraction is with the use of a dynamometer. With the added control of velocity, lengthening or shortening of the muscle has a further qualifier of isokinetic contraction (i.e., constant speed). By definition, there is no velocity reported with isometric contractions because length does not change and movement does not occur. Because it is easier to control for variability and therefore to measure, isometric contractions are the most frequently used in experimental research.[5]

There are a number of studies which have examined the magnitude of cross-education of strength under a variety of velocities. Housh & Housh[68] studied elbow flexion and extension and knee flexion and extension under 5 speeds, 60°/s, 120°/s, 180°/s, 240°/s, and 300°/s. At all 5 speeds there was significant increase in strength for elbow extension, knee flexion, and knee extension on the untrained side. However, elbow flexion did not show any cross-education of strength at any speed. More recently Farthing et al.[42] and Munn et al.[69] both found that there is greater cross-education at faster speeds. Interestingly, Munn et al. used an elbow flexion training program and found positive cross-education of strength whereas Housh & Housh did not. Farthing and colleagues studied at 30°/s and 180°/s on a dynamometer whereas Munn and team used a metronome at 1s or 3s for both the concentric and eccentric portions of the movement which equates to approximately 140°/s and 50°/s. Overall, the more recent literature provides evidence of greater cross-education at faster speeds and therefore, is more widely used in current interventions for studying the cross-education of strength.

The effect of training intensity on the amount of transfer of strength has not been well studied. Both low intensity and high intensity training have exhibited a cross-education effect.[31] Intensity can be

explained by discussing maximal voluntary contraction (MVC) or "all out" effort to recruit as many muscle fibers simultaneously for one task. Intensity was studied by Khouw and Herbert in 1998.[70] Their 51 participants were divided into 2% training increments. After testing elbow flexors isometrically 3 times, the largest force for each participant was recorded, and then their training arm and their training intensity was randomly assigned. For example, a participant whose peak force was 100N and was randomly assigned to train in the 45% range would need to do each training session only exerting 45N of force for each contraction. The results showed that there was a positive linear relationship between intensity and strength for the training limb; however, the untrained limb or cross-education effect was not influenced by training intensity.

Despite Khouw and Herbert not finding a correlation with training intensity and strength transfer, the vast majority of recent research has used ≥80% of 1 MVC or repetition maximum (RM) and almost all the cross-education of strength research has trained at more than 50% of 1RM. It is likely that researchers want to ensure a training effect and because high intensity yields greater strength gains, 80% of 1 RM is used most frequently. Discrepancy could also come from literature on electrically stimulated versus voluntary contractions in cross-education. It was shown that electrical stimulation resulted in greater cross-education of strength[71] and was determined because more motor recruitment was being achieved more transfer took place. In conclusion it is common practice to use standard training principles (~80% 1RM) for cross-education research.

The last training parameter under discussion in this review is volume. There are a number of components which make up volume such as the number of repetitions for a contraction, sets (the number of cycles of the number of repetitions), training days per week, and number of training weeks. A scan of all 80 experimental articles (reviewed for this review) and the included studies in the meta-analysis showed that most researchers are using 4-8 repetitions but the range is 3[72] to 30[73]. The range of sets is from 1-6 but typically 3 sets for each cycle of repetitions. The number of training days per week is

quite consistent; generally, 3 times per week but up to daily has been used. The number of weeks ranges from 3[55] to 12[62] but the average is 4 weeks. These volume parameters have not been standardised or controlled for across studies and therefore it is not understood whether they have any impact on the cross-education of strength. Volume does play an important role in the strength gained for the trained side. Because cross-education is believed to be proportional to the strength increases[1,5] of the trained limb, then maximising the strength gains by using ideal volume parameters would enhance the absolute increase on the untrained side.

Cross-education and participants with injury or illness

Despite most of the cross-education literature discussing the potential for clinical application, the vast majority of research has been done with healthy young volunteers. There have been 9 studies employing cross-education with people with injury or illness; the areas researched were 3 studies on stroke,[11-13] 2 studies on Anterior Cruciate Ligament (ACL) injury,[9,74] and 1 each for elective upper extremity surgeries,[75] knee Osteoarthritis,[10] distal radius fracture,[8] and multiple sclerosis.[7]

One of the first times cross-education was used in a rehabilitation setting was by Stromberg in 1986[75]; he included participants undergoing elective hand surgeries (ganglion cyst removal, carpal tunnel repair, digital nerve repair, wrist synovitis, collateral ligament repair, metacarpal trapezial fusion, and implant arthroplasty). The participants were divided into 2 groups: the control group (rest and elevation) and the treatment group (rest and elevation plus a training program for the unaffected side). The participants were immobilized for 3 weeks but measured once a week for the first 4 weeks and then at 6, 8, and 12 weeks post-operation. The results showed greater improvements for treatment group in ROM for the index finger and wrist, gross grip strength, and key pinch grip strength.

One research team, Papandreou et al., conducted research on the effects of a unilateral eccentric training program for soldiers in the Greek army who had undergone ACL repair surgery.[9,74] They found significant improvements for all 3 outcome measures; accelerated reaction time, Lysholm

Questionnaire (measure of disability), and strength, across both studies. The strength of the quadriceps on the side of reconstructed ACL had a decrease of 6% to 16% for the 2 experimental groups (3 and 5 training days per week respectively) whereas the control group had significantly greater decrease in strength, 37%. These results show great potential for cross-education to be rehabilitation tool after ACL reconstruction at both a strength and functional level.

The effect of cross-education on muscle architecture in older patients with knee osteoarthritis was studied in 2013.[10] The participants of this study trained in 1 of 6 groups: isometric right or left, isotonic right or left, isokinetic right or left. It was found that the isometric training group increased bilateral strength, muscle thickness, and fascicle length. These findings are novel; however, from a rehabilitation perspective cross-education is not an ideal treatment for bilateral osteoarthritis as it would be more effective to actively train both affected sides.

In another recent study to clinically apply cross-education, Magnus and team conducted a randomised control trial with patients who had a distal radius fracture.[8] The study included older females, averaging 63 years of age, who were casted for a distal radius fracture. During the 6 weeks of immobilization one group underwent graded, at-home handgrip training, using the uninjured limb. The results showed significantly greater strength and ROM gain in the fractured limb for the training group than the control group at 12 weeks. The final results show that the control group "caught-up" to the treatment (cross-education) group; however, the potential for cross-education to improve speed of recovery for fracture is evident after this study.

Most recently, Manca and colleagues[7] examined the effect of cross-education on people with multiple sclerosis who had a strength asymmetry in the dorsiflexors. Although they did not have a traditional control group, they found significant improvements after the 6 week intervention, in strength, the 10-meter timed walk test, and the timed-up and go test. The 6-minute walk test and quality of life measure did not reach statistical significance. Manca and colleagues made a concerted

effort to understand the clinical effect of the cross-education intervention by calculating the smallest real difference which is the smallest change greater than the error measurement. Both the 10-meter walk test and timed-up and go test were determined to be clinically significant at the post test measurement (6 weeks) but not at the 12 week follow-up. This study shows that cross-education is likely an additional modality for therapists to use with people who have asymmetric strength impairments as a result of multiple sclerosis.

Cross-Education and Stroke

Cross-education has been applied to people who have had stroke in 3 studies.[11-13] These studies have all shown the potential for cross-education to be beneficial, as increases in strength were found in the hemiparetic limb. Each study has contributed differently to the cross-education and stroke literature. The Mills and Quintana study confirmed considerable activation, 11-29% difference between resting and exercising conditions, in the affected limb. They were concerned that increasing strength would increase spasticity but it is now understood that this does not occur.[76] Dragert et al., in 2013, trained participants with chronic (average of 84 months post infarct) effects from stroke 3 times per week for 6 weeks.[12] Dorsi-flexion was trained with 5 sets of 5 isometric repetitions held for 5 seconds at maximum voluntary effort. A 2 second rest interval was provided between contractions, and a 2 minute rest interval between sets. One session was under supervision at the lab and the other 2 were completed at home. Dragert and team found dorsi-flexion strength increased by 31% in the more affected limb and 34% in the less affected limb.[12] These increases, when compared to the meta-analysis of cross-education effects in those without pathology, are more than 4 times greater.[1,5,12] They also used clinical measures to determine the effect of cross-education; however, only the timed-up-and-go scores were statistically different after the cross-education intervention.[12] In the most recent work, by Urbin and colleagues, the wrist extensors were the targeted muscle group for the cross-education intervention. They aimed to use cross-education for patients with greater impairment after stroke

because they believed that initially these patients would not be candidates for other, more traditional interventions. Active ROM on the more impaired side showed a significant improvement from pre to post measurements. Urbin et al. did not collect any clinical measures other than ROM; therefore, judging the potential for implementation is challenging. More research on the possible application of cross-education to patients with stroke is warranted. It is positive to see strength gains in participants who are outside the optimal (i.e. earlier) time frame for rehabilitation and it is therefore intriguing to ask whether the gains would be even greater in an acute stage. There are still many questions and potential uses of cross-education for rehabilitation of stroke.

Cross-education in clinical research is increasing in frequency and is slowly building the evidence-base in preparation for translation to clinical practice. The most important finding from the clinical research to date is that the cross-education of strength seems to translate at the same or greater magnitude compared to the traditionally used healthy participants. The clinical measures that have been used have not shown as robust of results as pure strength but, as Manca and team explained within their discussion, by only training 1 small muscle group, the likelihood that it would impact a more global clinical measure would be low. It is also very important to note that adverse events have not been found when applying a cross-education intervention. This is an essential finding before a new modality can be translated into practice. It is a positive sign to see the surge in clinical cross-education research. Nevertheless, the clinical cross-education literature to date has been unfocused. These clinical studies have examined a variety of diagnoses, used a variety of intervention parameters, and have all been conducted primarily in a research setting. Research in cross-education not only needs to show efficacy in controlled research settings; there must be evidence for its success in a clinical context with patients. Questions to be answered include, which patients are best suited for the intervention as well as the interventions' effectiveness in clinical practice. It is also critical to determine the likelihood of uptake of a cross-education intervention within the health system. The current body of literature has begun to

build evidence for efficacy but more research is needed to guide the future use of cross-education in practice.

Problem Statement

Cross-education was discovered in 1894[2] and has been extensively studied; however, only 9 out of over 80 experimental articles on the topic have studied participants who had any type of pathophysiology despite the majority of authors discussing the potential clinical applications of cross-education.[7-13,74,75] Of those 9 studies, only 3 have targeted people with stroke. A recent study with people with chronic stroke reported significant gains in dorsiflexion strength in patients after 6 weeks of training the strong side.[12] Additionally, Urbin and colleagues studied the effect of cross-education on participants with severely impaired wrists who were greater than 3 months' post stroke.[13] They found the paretic limb increased in active ROM. Despite recent findings that cross-education is efficacious in a stroke population; cross-education has not been applied or tested in a clinical setting and the previous work did not explore cross-education integrated into clinical practice. It is essential then to explore, as researchers, clinicians' perspectives, and the barriers and possible facilitators to implementation of this potential training strategy in a clinical setting. Therefore, a qualitative study with these clinicians is necessary to fully understand their perspectives on cross-education.

Objectives

The purposes of this qualitative study are:

1. To understand current practice of rehabilitation specialists (primary providers of upper extremity rehabilitation) when working with persons with stroke who have upper extremity impairments.
2. To gain an understanding of clinician knowledge of cross-education.
3. To ascertain clinicians' beliefs on the potential benefit of cross-education.
4. To explore potential areas of challenge for implementation of a cross-education training paradigm an acute rehabilitation setting.

Methods

Methodology

Exploration of clinician perspectives regarding a new intervention is best explored with a qualitative design. Creswell discussed several of the major qualitative methodologies including, phenomenology, grounded theory, case-study, narrative, and ethnography.[77] Phenomenology research is simply defined as the lived experiences of individuals, narrative research is the written or told stories of an individual about an event of series of events retold chronologically, grounded theory is to develop a theory about a process or action, ethnography methodology focuses on a culture-sharing group, and case-study research focuses on a specific real life event. None of these methodologies fit the objective outlined for this study. This study was grounded in the clinical realm and sought very pragmatic applications of the results.

Framework

Interpretive description was used as the qualitative framework to guide this study. Interpretive description requires an understanding of what we do and do not know.[78] It is grounded in the clinical realm and provides researchers a design logic by which they make design decisions. The aim of an interpretive description study needs to be to guide future decisions that impact real people and not generally to advance theorizing (p.36).[78]

Research Design

Focus groups were used in this qualitative study. Morgan[79] defines a focus group as, “a research technique that allows data collection through group interaction on a topic determined by the researcher. In essence, it is the researcher's interests that provide focus, whereas the data themselves come from the group interaction.” (p.6) Focus groups were chosen because they are a strong data

collection method for problem identification, and planning research design or interventions.[80] The nature of the topic was not sensitive or personal where talking with others could be uncomfortable and the group dynamic is beneficial for idea generation. It was recognized that when facilitating a focus group, it is essential to find a good balance between providing too much focus for the group and straying too far from the topic. Focus groups work best when used with people who have had similar experiences in the topic of discussion. As noted in the sample section, therapists were almost exclusively occupational therapists and each focus group was with therapists all working on the same stroke unit. Thorne suggests that obtaining maximal variation when sampling is crucial to fully explore potential themes.[81] It was therefore decided to collect the number of years each participant had been practicing as an occupational therapist.

Recruitment

One rehabilitation hospital and 3 acute care hospitals were selected because they are sites with stroke rehabilitation units. Because there is only 1 inpatient rehabilitation facility here, 2 focus groups were planned for that location to obtain as many perspectives as possible. Managers of the stroke unit departments were contacted and asked to help arrange the 45-60-minute focus group. Therapists were sent an invitation letter and consent form which explained the semi-structured topics of discussion.

Sample

As described previously, the arm is often more affected than the leg following a stroke, thus our sample was rehabilitation specialists who apply upper extremity interventions with persons with stroke. Ideally, this qualitative study will inform a future clinical trial with participants who have impairments in the upper extremity after stroke; therefore clinicians who work with this population were required. In Edmonton, occupational therapists are the primary discipline that works with patients with upper extremity impairment after stroke; however, other rehabilitation specialists were welcome to

participate in the focus group if they worked with the identified population. The sample consisted of a variety of therapists with different levels of experience and experiences working with this patient population. The sample was intended to offer a variety of perspectives based on the environment in which they work and their experiences.

The first focus group consisted of occupational therapists working at an inpatient rehabilitation facility. The second focus group, which due to limited participant availability, became an interview with 1 male therapist who worked inpatient rehabilitation. To protect the identity of the interviewed male at this facility his years of experience is included with the first focus group. The first focus group consisted of the occupational therapy manager, 4 other female therapists, and 2 male therapists. The years of experience of the first and second data collection sessions ranged from 3 to 30 years and had a mean of 15.6 years. The third focus group was at an acute care facility with therapists who worked on the stroke unit and the neurology/trauma unit. The group consisted of the occupational therapy manager, 2 female and 1 male occupational therapists, and 1 male and 1 female physiotherapist. Their years of experience ranged from 4 to 28 years with a mean of 11 years. The fourth focus group was at an acute facility with only occupational therapists. The group consisted of the occupational therapy manager, 3 females, and 1 male. Their years of experience ranged from a new graduate to 25 years with a mean of 11.6. The last focus group was at an acute care facility and consisted of 1 female occupational therapy manager, 1 male, and 3 female occupational therapists. Their years of experience ranged from 6 to 17 years with a mean of 10.8. The groups were of similar composition and the dynamics of each individual group was not overly influenced by experience and therefore experience was not explicitly used as an analytic lens through which to see the data.

Ethics

Ethics approval was received on May 12th, 2015 from the University of Alberta. The Northern Alberta Clinical Trials and Research Centre ethics approval was granted on June 10th, 2015. Covenant Health Research Operational/Administrative Approval was granted on December 4th, 2015.

Study Procedures

The data collection sessions took approximately 60 minutes. A facilitator led the discussion using pre-determined questions (see Appendix for semi-structured interview guide) and a second person took notes. The primary facilitator provided "focus" for the discussion and the second team member moderated the discussion by keeping track of time and asked any additional questions to elicit more group discussion. The semi-structured interview guide was developed to target several main areas: usual care for patients with upper extremity impairments after a stroke, knowledge of cross-education, perspectives on the phenomenon, and exploration of feasibility of a potential intervention. The interview questions were primarily open ended, designed to facilitate discussion and promote conversation. The participants did not have to answer all the questions. If there were additional discussion points that were related to the training program or proposed clinical trial the facilitator allowed the conversation to stray from the pre-determined questions.

Data Analysis

Data analysis was based on Braun and Clarke's guide for thematic analysis.[82] They provide 6 stages of data analysis which include (1) familiarizing yourself with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report.

Stage 1: Familiarizing yourself with the data

All data collection sessions were recorded on 2 hand-held digital recording devices and then immediately downloaded to a password protected drive at the University of Alberta. The primary investigator then transcribed, anonymized, and distributed the transcripts to the other 2 members of the analysis team. The team was comprised of the 2 members who conducted the data collection and a third member who only read the transcripts. The primary investigator read the transcripts a minimum of 3 times to ensure they had become fully immersed in the data. Initial reactionary notes were hand written on the transcripts. This was primarily analytic memoing.

Stage 2: Generating initial codes

Coding of 1 of the transcripts was done by all 3 members of the team. Codes, as Saldaña describes, should capture the essence or meaning of data.[83] The codes were discussed in an in-person meeting to ensure that each member was finding similar meaning in the transcripts. Thorne cautions to not code too firmly in the initial stages of data analysis[78] and therefore exact codes were not agreed upon at this meeting. The 2 members of the data analysis team who were present at all data collection sessions then coded all remaining transcripts. They then met in-person and discussed each transcript and the codes which they had created. The primary investigator explored different words which best represented the data. The coding was all done manually.

Stage 3: Searching for themes

Themes were considered meaning which runs throughout the data and a category was considered a grouping for which description is the primary purpose.[84] The primary investigator grouped all of the codes of similar meaning. When themes began to emerge, the original text associated with the grouping of codes was read together. The groups of codes were colour-coded to visually separate the original text. Groups of codes and in some cases individual codes became themes.

Stage 4: Reviewing Themes

The primary investigator had left a margin on the physical transcripts for reflexivity. Reasons and thought processes were recorded as the groupings of codes began to abstract further from the data. This reflexivity column helped to understand how the data were analysed. The groupings were then given a name and defined. The definitions provided an operational definition that described codes and units of information captured within a grouping of codes. This code book was presented to the other member of the data analysis team who had also coded all of the transcripts. They reflected on the groupings and the definitions and presented alterations. The third member of the data analysis team read all of the transcripts and also developed preliminary themes and categories. At this stage a figure was developed. The figure helped to capture the primary theme and categories. The figure aided in testing whether the data contained in each category were distinct from one another.

Stage 5: Defining and naming themes

A third in-person meeting was held to review the code book and figure. The operationalized definitions were agreed upon. The primary investigator used the code book to move exemplars from the transcripts into the primary theme and categories based off of the definitions for each.

Stage 6: Producing the report

The report was written with the figure as the primary focus. The exemplars chosen helped to tell the story of data.

Rigour

Determining what high quality qualitative research is and is not is a complex and controversial topic. Caelli et al. used 4 categories for generic qualitative research which are theoretical positioning, congruence of methodology or methods, rigor, and the analytic lens.[85] Morse and colleagues use verification strategies and compare them to the quantitative terminology of reliability and validity.[86] These strategies are methodological coherence, sampling sufficiency, developing a dynamic relationship between sampling, data collection and analysis, thinking theoretically, and theory development.[86] One

can see there is an overlap between these approaches. I will describe my theoretical position, demonstrate methodological coherence, and explain several verification strategies used throughout.

Theoretical Position

To understand and position myself in the analytic process, it is important to understand my motives, experiences, and or existing beliefs. I have been highly influenced by my undergraduate degree in kinesiology and health studies. I gained knowledge about disability and therapeutic recreation which allowed me to work as a Therapeutic Recreation Specialist (TRS) prior to enrolling in graduate studies. This knowledge and experience has shaped my beliefs and inspired my current research. While working as a TRS I wanted to bring in current research to my facility and recreation programme; however, I did not have the time or access. Also, I always felt that the changes which I made within my facility had to be subtle and believed to be the idea of the staff that had been at the facility the longest. Even though I was leading the recreation department, I believed that clinicians were resistant to change. I recognized that I had anticipated that the therapists recruited for this study would also be very resistant to change. However, I ensured that my belief did not influence the data collection or analysis processes. My desire to help research get to the hands that deliver change inspired my current research question. My experience also shaped my perception of all clinicians. The ability of an investigator to "bracket" their motives or experiences has long been debated.[85] I recognized that I cannot remove myself from the data analysis process; however, I tried to remind myself of my presuppositions throughout, by reflexive memoing.

Methodological Coherence

Despite not using a specific methodology, we have chosen methods best suited to the research question asked. First, the question asked was very clinical in nature. Second, focus groups were used to collect data. Focus groups are best suited to idea generation[79] which was imperative to answering our

question and to help hypothesize barriers, facilitators, and obtain a full exploration of the clinical perspective. Data analysis was based off of Braun and Clarke's approach to thematic analysis.[82] Although presented in a logical 6-step approach, the analysis was done iteratively with data collection. Data were collected, transcribed, debriefing about previous data collection was done, and then initial memoing was conducted prior to the next focus group. The methods chosen for this project were designed to meet the pragmatic clinical question posed.

Verification Strategies

Saturation is a contentious topic in qualitative research but one needs to know when to stop collecting data. I recognize that one can never achieve true saturation of data; however, it was felt that themes were found and reiterated throughout data collection. It is also suggested that when the focus group facilitator could predict where the conversation was going next without leading the group in that direction that a theme had been thoroughly explored.[79] During the fourth focus group, it was apparent that new ideas were not being generated; the last focus group was confirmatory of this. The primary difference between the groups was the amount of time and emphasis in which each group discussed the variety of topics presented to them.

A member check was done with the final results. The results were distributed to everyone who participated in data collection. Member checks ensure that the participants felt they were understood and the researchers have effectively captured the meaning of what was said. The members acknowledged receipt of the results but did not provide feedback of the results. This lack of response was taken to mean that the abstraction of the results was not misleading of what they individually felt the reported.

The last verification strategy used was peer debriefing with Dr. Wiart who was not part of data collection but has experience in qualitative research. Dr. Manns and I had collected the data and coded independently. Dr. Wiart read all the transcripts, coded 1 transcript and then met with Dr. Manns and

myself to ensure we were all coding the same meaning. I then continued data analysis and when I had developed themes and categories another peer debrief was held. These peer debriefing meetings presented a fresh vantage point from someone who was not as engrossed in the data but was still familiar. This was similar to an audit; however, it was integrated into the entire data analysis process.

Results

After analyzing data from 5 data collection sessions, which included 22 participants, 1 theme was found. The theme was further explained through 3 descriptive categories as illustrated in Figure 1.

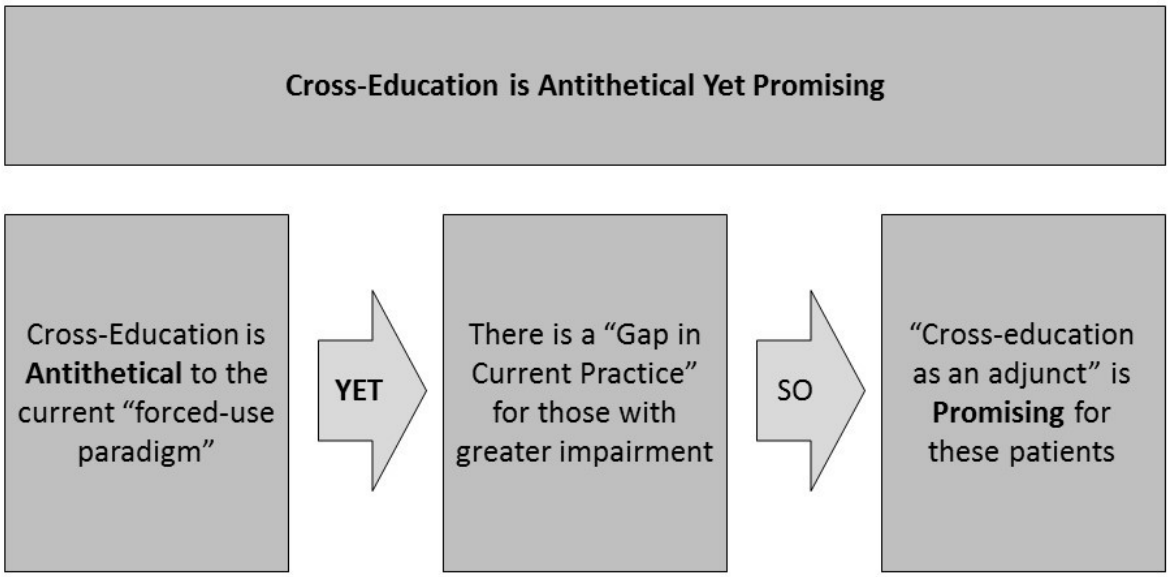

Figure 1: Relationship of theme and categories. Bold face text is the theme embedded into the categories which are highlighted by quotation marks.

Antithetical Yet Promising

Cross-education is antithetical yet promising was the lone theme which was reiterated in every data collection session. One therapist explained by saying "It goes against the grain of everything we were taught as therapists and everything we know about" yet later they expressed "it could have massive implications". These quotes were perfect examples of the theme. The primary theme was captured in 3 descriptive categories. The therapists described working in a (1) forced-use paradigm, yet they also described how that paradigm did not meet the needs of all of their patients. They recognized this as a (2) gap in current practice. They also hypothesized that (3) cross-education used as an adjunct

could be effective within their current practice for specific patients. Figure 1 shows the primary theme woven between the 3 categories.

Forced-Use Paradigm

Therapists explained that cross-education is directly opposed to the current paradigm in which rehabilitation for patients with upper extremity impairments after stroke is delivered. This paradigm can be called the forced-use paradigm. The therapists explained their current practice by describing the types of assessments and interventions they would use as well as how those interventions would be delivered. In alignment with the Canadian Stroke Best Practice Recommendations, the focus of the assessment and intervention was on the more affected limb. The interventions described by the therapists exemplified the forced use paradigm. They reported they used auto-assisted exercises, Constraint Induced Movement Therapy (CIMT), Electrical stimulation, Neuro-Developmental Treatment (NDT), placement/positioning, proprioceptive neuromuscular facilitation, stretching, vibration, wax therapy, and weight-bearing. The only interventions which utilized the less affected side were GRASP [87], Mirror therapy, and mental imagery (no limbs involved). The heavy emphasis treating the more affected limb was a clear indication of forced-use paradigm. Therapists recognized that cross-education is "a little contrary to what some things say" and "it's very interesting because it is very opposite to constraint." "It goes against the grain of everything we know, right? Because you want to treat the deficit, right?" The other challenge that was noted by the therapists was that they would have to do a more thorough assessment of the less affected limb. "And maybe even further assessment, because you'd have to do a pretty thorough assessment before and after of both limbs to make sure you're actually making gains whereas I don't always look at the unaffected side that closely."

Mirror therapy, one of the therapies that incorporates the non-affected arm, was recognized as overlapping with cross-education. Mirror therapy however was reported as not being used too

frequently despite its' evidence level. Mirror therapy was also not used because their patients' "felt it was too hoaxy". One therapist stated that,

> "I actually find like when I'm bringing the mirror out and covering people's affected side and getting them to actively do stuff it's almost like, I feel like it's a last, like in my own clinical judgement, I'm like I don't, like everything we've been doing hasn't been working or you know the lesion is such that we're in trouble with this arm or whatever so it almost feels to me like a last ditch attempt sometimes."

Therapists held concerns that mirror-therapy was a last resort or not as efficacious as other therapies. They also identified barriers to implementing cross-education which were similar to that of mirror-therapy. Cross-education is not only antithetical to the rehabilitation paradigm in which the therapist works, it would be counterintuitive for the patients and families. The therapists expressed there would be a need for education for all the parties involved.

> Therapist 1: And I think it not only goes against what we know as therapists, just even in the general public it would be really hard to explain to someone, "Oh no, we're only going to work with this arm we already know works." You're going to need to have resources to back that up. It would be really hard to explain it.
> Manager: Or their family members. "Why are you not working that arm? This arms fine; work on this one."
> Therapist 3: And probably physicians, right?
> Therapist 1: And lots of education on our part for why we're choosing to do what we're doing.

Overcoming the antithetical nature of this phenomenon would be essential for patient-therapist buy-in and engagement.

Therapists had concerns with cross-education in relation to their current practice. They expressed concern that cross-education might take away from work with a patient with neglect. "[If] you're trying to get, work on an inattention or neglect, something that's more constant throughout the day, it might draw away from the cues you're trying to build into them, to be more aware of that other side." Using the forced-use paradigm causes the patient to attend to the limb they may be neglecting and cross-education is antithetical to the current strategy. The forced-use paradigm's purpose is to encourage as much movement on the affected side as possible; cross-education is opposite and had the therapist question if they might be encouraging learned non-use. "If you really overdo it you're going to

encourage compensation?" Therapist were also concerned that currently they had very limited time with their patients would it be "ethical" to spend time focusing on the less affected side. Because of the antithetical nature of cross-education, therapists were concerned that this new modality may not be the best investment in comparison to what they currently implement.

Gap in Current Practice

Despite concerns, there was general agreement that treatment options for those with severely impaired arms were less available and less effective than options for persons with hemiplegia who had better arm recovery. One therapist explained that over the last 3 to 4 years he had "developed skills" for patients with more severely impaired upper extremities; yet he found that he still did not have the intervention options available that he would like. "I would say that I do feel limited. I would like to have more, more options, different options." Other therapists reiterated this point: "…there's not a lot we can do with those patients at this point that I know of", "I used to work with more moderate to severe stroke and longer term rehabilitation where people had like Chedoke <3 [assessment level of impairment, 1 is the lowest, no active movement] and they had been at this point for 6 months, a year, and still haven't seen recovery", and

> "To be honest a lot of our patients are stage 1, 2 [the most severe levels of impairment] to start with the arm and just through experience the legs come back, the arms, a lot of them do not and they start at stage 1 and they leave here at stage 1. That's a lot of our patients."

Therapists noted that often their patients had factors which limited their ability to utilize various interventions because these interventions are designed for patients with specific types of impairment. "The few options that I have available… sometimes…I can't really work with some of them, like electrical stimulation if people can't tolerate it that becomes a big challenge…" Two interventions, CIMT and GRASP, have strong evidence for upper extremity rehabilitation; however, it was commonly expressed that patients with more severely impaired upper extremities could not participate in those interventions because they did not have enough movement in their wrist. Severe impairment also limited the

therapists' ability to prescribe unsupervised work because of safety, as many patients with more impairment have shoulder pain. This requires extra support and therapists were more cautious about the prescription of additional unsupervised exercises for that limb. Overall, therapists expressed that they did not have the suitable interventions for patients with severe upper extremity impairment after stroke.

Cross-Education as an Adjunct

Across all focus groups, therapists recognized the promise of cross-education under the right circumstances and for the right patient group. After identifying that patients with greater impairment were less likely to improve and that therapists had fewer rehabilitation modalities for this patient group, they talked about how cross-education could help this group. One therapist liked the idea of trying cross-education because "It would give us another option because there's not a lot we can do with those patients at this point that I know of. This would be another, like a new modality." They discussed which patients would be best suited for the phenomenon. "I think for me, if they have nothing on the affected side; if they're completely flaccid and they have nothing maybe I would feel less worried about strengthening the unaffected side because they essentially, at this point, have nothing." Therapists hypothesized that they would be most comfortable prescribing this treatment for someone who had a flaccid arm.

It was felt that this group of patients with severely impaired to flaccid upper extremities needed more intervention options, not only for rehabilitation but also for self-efficacy. One therapist explained that she had a patient with a flaccid arm but was "so highly motivated" that she thought cross-education would be very suitable for him. "I just think for his own, his own feelings of benefit and rehab he might feel like we're actually doing something."

Because rehabilitation is demanding it was thought that for both, patient buy-in and continuation of rehabilitation, cross-education would be very a favourable option. One therapist

explained, “A lot of patients might like it though too, just because they’re… it’s so easy. It’s a change from struggling for a while.” Another therapist explained that they thought;

> “…the perfect patient for this sort of thing would be someone who does fatigue quite easily and so can’t participate with their affected side that well, so they want an alternative, so you can provide them with that alternative to you know still have some sort of engagement. I don’t know but outside of therapy most patients want to do something. Often most patients would want to do it.”

This led to many therapists seeing promise because cross-education (i.e., working with the stronger arm) was safer to provide as homework, or it could be delivered in a group, or family could help administer the intervention. Many patients with more impairment have severe shoulder pain which made the therapists more cautious about the prescription of additional unsupervised exercises for that limb. They felt that training on the stronger side was a safe option for patients to engage in when not supervised by a therapist or therapy assistant. Therapists then recognized that families could also support this homework style treatment.

> “I think also that this is something that families can do safely. Like you know we are always leery about letting families do something with the affected arm. You know because the shoulder is always critical and all that. So getting families involved to do something with them on the unaffected side in my mind is going to be a lot safer because we're not worried about other things with the affected side. So and then they could have repetition and you know because it's repetition, repetition, repetition, right?”

Therapists also thought that cross-education was promising because they potentially did not have to deliver the intervention yet it could provide additional rehabilitation.

> “I think for something like that for me personally I would probably even refer to a therapy assistant at that point and I don't think it's something that I would need to be there and actually facilitate. So time might be a factor but if, if that's an option that would be okay.”

Overall, cross-education was seen in a positive light because it was a safe intervention that could be delivered by a therapy assistant, in a group, self-administered, or assisted by family members.

Therapists also talked about mental imagery and mirror therapy as interventions with good evidence, but interventions that were not used frequently. They saw similarities with cross-education, and as such that overlap suggested promise for cross-education.

> "It goes against the grain of everything we know, right? Because you want to treat the deficit, right? You do, but I can also see benefits of like having like visual imagery, like mirror therapy all that stuff, there's a benefit in all of those things but we used that in combination with other therapy not solo."

This was an excellent example of how they could see that current practice influenced their perspective on the likelihood of efficacy for cross-education but also that it would need to be embedded into practice as an adjunct.

The other noted benefit of cross-education was protection for the less affected side. "…if we can get his right arm super strong then maybe he could be more functional." Another therapist explained their original rationale for doing exercises on the less affected side.

> "I've always thought that, well, you know we want to protect your shoulder girdle. We want this arm to be strong and healthy because we want you to help with bed mobility or we figure we can get you independently using like a sask-a-pole so want that arm strong."

They were happy to know that a more focused approach such as cross-education could have 2 benefits; to protect the less affected side, "When we do the outcomes at the end sometimes we see that strength go down and they get injuries from over compensating." as well as potential transfer of strength to the more affected side. Cross-education was seen as promising as an adjunct because it was safe, another modality for patients with severely impaired upper extremities, an easy way to engage and increase volume of rehabilitation for patients, and a good way to protect the less affected side from compensation injuries.

Discussion

The theme that "cross-education is antithetical yet promising" has led to a greater understanding of factors that will have implications for future clinical research and potentially a rehabilitation intervention. The therapists clearly explained that they worked in a forced-use paradigm and they recognized that cross-education was opposite to the majority of their work. This reaction was anticipated because the Canadian Stroke Best Practice Recommendations, which guide practice in Canada, have 2 general principles for upper extremity rehabilitation which describe the forced-use paradigm.[3] The second principle states, "ii. Training should encourage the use of patients' affected limb during functional tasks and be designed to simulate partial or whole skills required in activities of daily living (e.g. folding, buttoning, pouring, and lifting) (Evidence Level: Early-Level A; Late-Level A)."[3] Despite this obvious focus on the more affected limb, it is important to note that there are treatments with high-levels of evidence that utilize the less affected limb.[3] Mirror therapy is one of these treatments. Mirror therapy utilizes movements of the less affected limb while the patient watches those movements in a mirror. It is given the same level of evidence as CIMT which is exclusively for the more affected limb. Because mirror therapy is contradictory to the second guiding principle the utilization in practice is likely negatively impacted. This negative impact was reflected in one of the therapist's comments about mirror therapy, calling it a "last ditch attempt"; cross-education may face a similar issue. Cross-education's opposition to the forced-use paradigm will need to be addressed so it can translate to clinical research and practice.

Therapists had some difficulty envisioning cross-education embedded in their practice. A cross-education intervention for the wrist extensors, with strength and ROM as the goal, was proposed. Therapists were a bit wary because strength and ROM are not necessarily functional outcomes. This is a valid concern. Both general principles for upper extremity rehabilitation after stroke make recommendations for the types of tasks in which the patients should engage and the emphasis is on ADL

and functional activities.[3] The second general principle for upper extremity rehabilitation in the Canadian Stoke Best Practice Recommendations is, "i. Patients should engage in training that is meaningful, engaging, repetitive, progressively adapted, task specific and goal-oriented in an effort to enhance motor control and restore sensorimotor function (Evidence Level: Early-Level A; Late-Level A)."[3] Although the cross-education of strength and ROM is not necessarily functional, there is support in the literature for interventions that address impairment mitigation (i.e. strength, ROM), to allow more successful practice of functional activities. Winstein and colleagues in their paper describing the Accelerated Skill Acquisition Program, emphasize the importance of working on impairment as "capacity building."[88] They suggest that capacity, motivation, and skill are all required to successfully integrate the impaired limb into daily activities. Cross-education strength training for people with severely impaired upper extremities after stroke is an excellent example of a capacity building activity. Cross-education of strength could be applied as a kick-start for the more affected limb especially when it is severely impaired. As capacity is built, the patient would then be able to engage their arm in more meaningful, task specific training.

Implementation of Cross-Education

Why would cross-education work?

One of the most important results of the study was that therapists believed that cross-education is a promising adjunct intervention. Therapists felt that cross-education could be delivered in a variety of formats; that it was safer than other interventions for unsupervised therapy; and they hypothesized that patient buy-in and adherence would be better because of the easy nature of the intervention. These benefits make the likelihood of implementing a cross-education intervention very high.

Therapist time is limited in rehabilitation environments and having an intervention which can be delivered in a variety of formats can help to lessen the time burden. Therapists described that they offer

1-1 therapist and 1-1 therapy assistant delivered interventions. They also discussed that they have groups which are designed by the therapist and delivered by either the therapy assistant or therapist. Therapists also provided homework style interventions for their clients. The therapists in our focus groups felt that cross-education could fit into any one of these formats depending on the needs of the client. This makes cross-education extremely flexible and easy to implement.

Another positive finding is that cross-education was considered safer than other non-supervised treatments. Many patients with severely affected upper extremities will experience shoulder pain.[3] As the therapists explained in our study, they are reluctant to prescribe homework for the more affected side if the patients' shoulder requires support and protection. The Canadian Stroke Best Practice Recommendations suggest that in the flaccid stage protecting the shoulder joint is paramount.[3] During scheduled therapy, clinicians are trained in providing treatment while still protecting the shoulder. Shoulder care education for the patient and the family is highly recommended but there is still risk when exercises continue unsupervised. Cross-education is done on the less affected side and therefore is safer for those who pose a risk of hurting themselves with independent therapy on the more affected side.

Therapists explained that adherence is often challenging; yet it is critically important for the effectiveness of any intervention. Cross-education is likely to have better adherence than other homework style interventions for clients with severely affected upper extremities. The COM-B model is a model of behaviour change that helps to explain why cross-education interventions may see better adherence than other interventions. The COM-B model[89] stands for capability, opportunity, motivation, and their influence on behaviour. In the area of capability, the patients need to have the psychological and physical capability to complete a task. Therapists were excited about cross-education because it is an intervention in which patients with more severely affected upper extremities could still engage compared to other interventions, therefore cross-education meets every patient's physical capabilities. They also said that because cross-education was so easy, a lot of people might like it. Others believed it

would even increase their patients' self-efficacy and belief in the whole rehabilitation process because they would have success with cross-education. The ease of this intervention can positively influence a patient's psychological capability. Opportunity is in both a social and physical context. Therapists explained that they were reluctant to use cross-education in one-to-one occupational therapy sessions; however, they did feel that if they taught cross-education their patients would have plenty of opportunity to build-in independent cross-education therapy time. Lastly, motivation in the model is where an implementation intervention is required. Motivation is either automatic, which are our needs, or reflective, which are our pre-planned efforts. We cannot easily alter automatic motivation for needs such as food, water, rest, and safety; however, reflective motivation could be influenced with an educational implementation intervention. Therapists would have to educate their patients that cross-education will help their more affected side. They could potentially explain it physiologically but more likely they would need to stress that cross-education is a kick-start for the more affected side so that they can get enough movement to engage in a variety of other proven therapies. This education is necessary to help the patient feel motivated to pursue and adhere to the cross-education intervention. If efficacy for cross-education as a stroke rehabilitation intervention continues to build, the effectiveness will not likely be hindered by adherence to the intervention.

What factors may limit the impact of cross-education?

Although there are many positive reasons why cross-education could be successful in practice, therapists were thinking about the interaction of neglect, cognition, and limb dominance with the promise of cross-education. After a stroke, unilateral spatial neglect (USN) can result. USN is defined as reduced awareness of stimuli directed to the side contralateral to the lesion and is associated with poorer functional outcomes.[90] There are many existing treatments for USN, for example, visual scanning therapy, and prism adaptation[3]; however, most often an environmental change is used to bring attention to the neglected side. The environment, including people, can be oriented to the left of the

patient, which forces the patient to attend to stimuli on the neglected side. The therapists were concerned that cross-education would take away from this continuous effort made by the rehabilitation team to draw the patient's attention to the affected side and incorporate it as much as possible. Currently, there is not enough evidence to know whether a 15 minute adjuvant therapy would take away from environmental training to lessen the effects of neglect.

Further confounding the potential of cross-education is the issue of limb dominance. As previously discussed in the literature review of the thesis, Farthing and colleagues have found that the transfer of effect primarily takes place by training the dominant limb and measuring the effect on the untrained non-dominant limb; no transfer was found when training the non-dominant.[39] Therapists discussed this issue without knowledge of the current literature. They immediately wondered, depending on impaired side, what would result in the greatest transfer. Also, there is not enough evidence to know the impact of limb dominance on the transfer of strength after stroke. It is therefore recommended that a future trial not exclude patients with neglect and record limb dominance and adjust for it in analysis.

Clinicians described that they felt that they would likely prescribe cross-education to a patient with a very severely affected upper extremity; yet they wondered if a patient's cognition would influence how they would deliver the intervention. Stroke severity predicts both function[91] and cognition[92]; therefore, focusing on patients with a more severely affected upper extremity will increase the likelihood of cognitive impairment in those patients. Therapists felt that they could prescribe cross-education as a homework style intervention for those who could cognitively attend and follow-through with the exercises. Although, delivering cross-education outside scheduled therapy time is a positive with this subset of people with stroke it may be less effective due to cognition.

How can we make cross-education work?

Knowledge translation Canada suggests that Pathman's "Awareness to Adherence" process can be used to guide implementation interventions.[93] Pathman explains that for an implementation intervention to influence health care provider behaviour, first there must be awareness of the new evidence.[94] Within our sample of rehabilitation specialists, it was noted that cross-education was not known and it was predicted that people would not intuitively understand. When the discussion shifted from current practice to cross-education, existing knowledge of cross-education was discussed first. Participants were unaware of the meaning of cross-education. They theorized a definition but the individual words, "cross" and "education" did not lead them to the actual definition. Other terms such as, "exercise overflow", "cross-transfer", "cross-exercise", "contralateral effects", "contralateral strength", "contralateral motor overflow", which have been utilized in the literature, were presented to the therapists. These terms did not help the therapists theorize or recognize the definition for cross-education. Awareness is crucial to successful integration of a new intervention into clinical practice.[94] One therapist in our focus groups explained that, "…potentially the only reason we're not doing it is because we don't know about it, but I would have to know that it had value." Increasing the awareness is the first step to ensure that all parties buy-in to the new treatment.

Because of the antithetical nature of cross-education, therapists recognized that education would be a prerequisite for patient, family, and health care provider buy-in. Pathman's second stage is "agreement," which is the therapist belief in the intervention.[94] Pathman suggests an enabling strategy such as small group learning,[94] could help to facilitate therapist buy-in. In this small group learning the evidence would need to be presented to the clinicians. The therapist's belief in the intervention is dependent on their understanding of the evidence around cross-education. Currently, there is strong evidence for cross-education in the healthy population but the level of evidence of cross-education for people with upper extremity impairments after stroke is poor and the evidence base is still developing.

The Canadian Stroke Best Practice Recommendations development team used the following criteria to determine the levels of evidence for the most recent update.[3]

A. Evidence from a meta-analysis of randomized controlled trials or consistent findings from two or more randomized controlled trials. Desirable effects clearly outweigh undesirable effects or vice versa.
B. Evidence from a single randomized controlled trial or consistent findings from two or more well-designed non-randomized and/or non-controlled trials, and large observational studies. Desirable effects outweigh or are closely balanced with undesirable effects or vice versa.
C. Writing group consensus and/or supported by limited research evidence. Desirable effects outweigh or are closely balance

Using these criteria the cross-education literature with the healthy population would be classified as level A. The most recent systematic review and meta-analysis consisted of 16 randomised control trials.[1] The cross-education effect was found to be 7.6% increase of strength on the untrained limb or approximately half of the strength increase on the trained limb. This meta-analysis and its predecessor (Munn et al. 2004)[5] proved that the cross-education phenomenon is real and not a product of placebo or baseline measurement. The definition of level A evidence also states that "desirable effects clearly outweigh undesirable effects." In cross-education, the undesirable effect would be considered the lack of transfer to the untrained side and not a detrimental or adverse event. Therefore, the greater concern is whether the magnitude of the effect is clinically significant.

To date, 3 articles have been published on cross-education and stroke.[11-13] Applying the aforementioned level of evidence criteria, the cross-education and stroke literature would receive a level C. Mills and Quintana in 1985 conducted an observational study in which they explored muscle activity of the paretic limbs before and during unilateral training of the less affected side.[11] They recruited 11 people in the acute stage post-stroke and found that higher intensity training increased muscle activity greatest in the homologous muscle group. The second study, by Dragert and Zehr, conducted a single group non-randomized trial on the effects of 6 weeks of isometric dorsiflexor training in a sample of people with chronic impairments after stroke.[12] Although they were not able to eliminate

the effect of baseline measurement, they found a 34% increase in strength on the trained side and a 31% increase on the untrained paretic dorsiflexors. This increase is drastically larger than ~8% reported in the healthy population meta-analyses.[1,5] The most recent study by Urbin and colleagues is the only study to examine cross-education in the wrist extensors of people with impairment after stroke.[13] They trained 6 participants for 4 weeks and found significant improvements in active ROM on the more affected limb. This study utilized a neurologically intact control group which can show that the intervention provided had a cross-education effect; however, it does not allow for direct comparisons between groups. In summary, cross-education for people with stroke has not caused any adverse events; however, because there have not been any well conducted randomised control trials the level of evidence must be considered level C. This will be important information to convey to therapists as they work to achieve buy-in for cross-education with patients and other health care providers.

The third and fourth stages of Pathman's process are "adoption" and "adherence." It is suggested that workshops can be used as an enablement strategy for the adoption stage. In the case of cross-education, an information session would need to be held for all health care providers, a training session for those delivering the intervention, and information resources to give to family members such as a pamphlet with simple rationale and a description of the exercise protocols. The pamphlet would be easy for the patient and their family to refer to in their room when unsupervised. These simple approaches would help to ensure buy-in from all parties and successful integration of the new treatment into practice. Adherence as previously discussed would be very likely because it is easy, safe, and patients' have the capability to engage in the exercises.

How do we make cross-education work in clinical stroke research?

Future trials in the clinical realm are needed. These trials need make methodological improvements, and take previous discoveries in cross-education research into consideration (i.e., limb dominance). Also, to move cross-education specifically into clinical stroke research, it is fundamental

that the variables influencing stroke recovery such as time from infarct to rehabilitation be assessed and accounted for in future trials and analysis. Most importantly the information learned from the participants of this study need to be considered to produce high-quality and meaningful results. These study specific factors will be discussed below.

Cross-education is highly susceptible to learning and placebo, as well as the influence of baseline measurement on strength gain.[1] Because of these challenges, using an appropriate design is essential to detect a true cross-education effect. With strength training protocols it is impossible to use a wash-out period and with the challenges of learning and placebo, a single group design is not recommended; therefore, a two-group randomized control trial (RCT) is the most acceptable design. The phenomenon has been established in the healthy population[1,5] but the current cross-education and stroke evidence has yet to show conclusive evidence that the effects are real and lasting. Again, a two-group RCT is needed to determine the potential of cross-education for people with impairments after stroke.

Cross-education interventions can also be influenced by the amount of arm use for both the trained and untrained limbs outside of formal intervention periods (daily use). In a clinical setting, daily use and usual care need to be measured in order to learn about the independent effect of a cross education intervention. We suggest using accelerometers on both wrists to assess the amount of movement in each arm throughout therapy and daily use. Accelerometry has been used with people with upper extremity impairments after stroke[95] and would help to ensure that there are no group differences in a RCT.

Examining the effect of any new intervention in stroke rehabilitation is challenging because of the variability of infarct and subsequent recovery. Despite this variability there are several variables which are known to influence recovery and should be measured throughout a clinical trial. It has been demonstrated that patients who receive earlier intervention (<20 days) post infarct have 6.11 (95% CI, 1.38-18.03) times the likelihood of a positive therapeutic outcome.[96] Thus time since stroke should be

reported with any intervention. Depression and spasticity are also challenges frequently experienced by people with stroke. Both may influence the effect of a new intervention; however, they can be accounted for. It is also recommended to fully describe the sample by assessing the level of impairment and stroke location, identifying medications, and describing comorbidities. It is recognized that including all of these variables makes the analysis more difficult; however, it necessary to include patients who truly represent stroke recovery and not just those who are the ideal RCT participant.[97]

Although the underlying cross-education mechanisms are not understood, limb dominance has been shown to have a great moderating effect on the magnitude of transfer in the upper extremity.[39] It is therefore important to include this variable in analysis. It is recognized that the impaired limb is not a choice when addressing rehabilitation after stroke. Training the non-dominant limb will be inevitable in many cases but assessing if cross-education works in this direction is necessary for application of the new treatment.

Our current qualitative study has provided insight into how to best integrate a cross-education trial or intervention into clinical practice. It was learned which patients' likely would benefit most from this intervention. We also learned that education for everyone involved was a prerequisite to implementation and that the intervention could be delivered in a variety of formats. Although a RCT has been suggested, it is also necessary to understand this phenomenon in the clinical context which is a pragmatic or effectiveness study design. Singal, Higgins and Waljee define effectiveness through 5 simple categories.[98]

> Question: Does the intervention work in real-world practice?
> Setting: Real-world everyday clinical setting.
> Study population: Heterogeneous population with few to no exclusion criteria.
> Providers: Representative usual providers.
> Intervention: Applied with flexibility. Concurrent interventions and cross-over permitted.

Cross-education needs to be conducted in inpatient rehabilitation because it will likely have the greatest effect in a subacute population with stroke. Although the therapists from our focus groups suggest that

people with more severely impaired upper extremities would be ideal candidates for a cross-education intervention, those with comorbidities should not be excluded. As mentioned early, the delivery would be dependent on the patient's needs. Those patients with greater cognitive needs would likely receive the intervention in a group or 1-1 setting; whereas, others may do the cross-education intervention on their own as homework. Cross-education should be conducted along with the facilities usual care because we now know that therapists would be resistant to using cross-education as a solo treatment.

Although cross-education is somewhat contradictory to the Canadian Stroke Best Practice Recommendations, it is time for it to be tested in a clinical setting. By including all of the factors learned in this study and the previous discoveries found in the literature for cross-education and stroke rehabilitation, a future study will be able to not only assess the efficacy of cross-education for this population but better understand how cross-education integrates into current clinical practice.

Limitations

A limitation of this study was that other data sources were not collected to triangulate the results. The therapists identified a gap in existing practice. To further substantiate that finding, observational data from the National Rehabilitation Reporting System could have been requested to confirm the limited recovery of patients with more severely affected upper extremities in the Canadian rehabilitation system. Also, a chart review could have been conducted to confirm that this same patient group does not receive the same variety and intensity of rehabilitation as those with greater arm function.

The other primary limitation of this study was that we only collected 1 perspective. Implementation of a new intervention impacts several levels of health care, including the patients, the health care providers and the organization. It would have been beneficial to have conducted focus groups with patients recently discharged from acute rehabilitation facilities to understand their perspectives about implementing a counterintuitive treatment. We would like to recommend that

future trials conduct a qualitative study with the participants who received cross-education therapy to understand their experience. This could be valuable information for refining and further developing the intervention.

Conclusion

The aim of this study was to understand the perspectives of rehabilitation specialists on the potential of a new intervention to rehabilitation called cross-education. The primary theme found was that cross-education is antithetical to the current rehabilitation paradigm for upper extremity impairment after stroke, but it was still viewed as a promising adjunct therapy. This finding should inspire future research in both the efficacy and effectiveness of this intervention.

If cross-education as a stroke rehabilitation intervention were to be added to the Canadian Stroke Best Practice Recommendations its current level of evidence should be considered level C. However, as a result of our study we know that there is a place within current practice for such an intervention. The rehabilitation specialists identified that within their current practice those patients with more severely affected upper extremities had fewer efficacious intervention options. This now identified gap within practice will likely help a future cross-education intervention to succeed in implementation.

We also know that although cross-education is opposite to what is typically done in existing practice, therapists recognise that there is promise as an adjunct therapy. It can be delivered in a variety of formats such as 1-1, or group, or independently. Therapists felt more comfortable prescribing cross-education as an unsupervised, homework style intervention than other existing intervention because cross-education is on done on the less affected side and therefore safer. This will help with the success of the translation of this intervention into clinical practice.

Although the efficacy for cross-education and stroke rehabilitation is not yet established, the clinical environment is ready for it to be tested. Future research needs to consider the results of this study as well as the previously established findings in the cross-education literature. There is an opportunity to trial this antithetical yet promising intervention.

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Appendix A: Focus Group Semi-Structured Interview Guide

Introduction to focus group session

- Introduce the facilitators
- Thanks for coming and welcome
- Housekeeping issues (toilets, beverages etc.).

The purpose of this focus group is to learn what you do now for a patient with limited arm movement and your thoughts on a new training intervention.

You were identified you are one of the primary health care providers who work in upper extremity rehabilitation and can provide valuable information on current therapy and the potential benefits and pitfalls of the proposed intervention.

Outline and timing of the session:

- Focus group approximately 1 hour
- How the session will be organized
    - Introductions
    - Hand out information sheets and consent forms
    - Ask for clarifying questions during the introduction
    - Discuss tape recorder
    - Stress this session as a focus group interview (dynamic process of group work)
    - Rules about agreeing, disagreeing, changing one's mind, respecting the opinions of others
    - Confidentiality
    - Discuss tape recorder and note taking by facilitators
    - Sign consent
    - Turn on tape recorder
    - Discussion to begin

Typical Treatment for patient type

We would like to know a bit more about the treatment for your patients.

1. Could you tell me about a typical treatment day for someone with limited arm function? (i.e. Chedoke <3)
    a. What sort of things would you do?
    b. Is it completely individualized?
    c. How would you expect that patient to progress? Or – one of the important things for us to understand before starting a study is what usual progression of patients is now. If we say that the typical starting point is Chedoke score or 3 or lower, is it possible to comment on a typical end point for those patients, at D/C from GRH, for their arm function?

2. Is the arm part of the discharge criteria?

3. How many patients would you say access OT services for arm treatment after discharge?

4. What type of assessments do you use?

Knowledge of the Topic

As you know, we are exploring options for something called cross-education – for use in clinical situations with patients with stroke.

5. Have you ever heard the term Cross-Education?
    a. What does it mean to you?
    b. Have you ever heard of “exercise overflow”, “cross-training”, “cross-transfer”, “cross-exercise”, “contralateral effects”, “contralateral strength”, “spill-over”, “contralateral motor overflow”, “cross-over effects”, “bilateral effects”

Perspectives on implementation and paradigm shift

We are proposing that cross-education be used in addition to usual treatment with patients that have very limited movement on the more affected side. We think that cross-education could be used with people who have very limited arm function and may facilitate their ability to eventually participate in other therapies. We were thinking of implementing a wrist-extension strengthening program. It would not take much patient time; approximately 15 minutes in the day.

6. What are your thoughts on this?

    a. Practicalities

    b. Opposite Approach

7. Can you see potential benefits of cross-education?

8. Are there challenges you foresee in introducing cross-education in a clinical setting?
    a. Probe for challenges specific to GRH