TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENT	iii
ENGLISH ABSTRACT	iv
THAI ABSTRACT	vi
TABLE OF CONTENTS	viii
LIST OF TABLES	xi
LIST OF FIGURES	xii
ABBREVIATIONS	xiv
CHAPTER I INTRODUCTION	
1. Rationale	1
2. Research question and hypotheses	4
3. Purposes of the study	5
4. Advantages of the study	5
CHAPTER II LITERATURE REVIEW	
1. Cerebral palsy (CP)	
1.1 Definition of CP	6
opyrigh 1.2 Crouch gait in CP ang Mai Univers	8
1.3 Knee function and crouch gait in CP	10
1.4 Muscle weakness in CP	14
2. Intervention for strengthening muscle	
2.1 Conventional strengthening program	15
2.2 Strengthening muscle in CP	16

viii

	2.2.1 Outcome measurement in related to muscle	20
	strengthening in CP	
	2.2.1.1 Muscle strength	20
	2.2.1.2 Muscle spasticity	22
	2.2.1.3 Range of motion	23
2.3	B Electrical stimulation	25
CHAPTER III	METHODS	
1.	Participants	32
2.	Study design	33
3.	Equipments	34
4.	Outcome measures	35
5.	Procedures	35
6.	Data analysis	44
7.	Location	45
CHAPTER IV	RESULTS	
1.	Demographic data of the participants	46
2.	Comparisons of normalized QMVIC, quadriceps lag,	47
	angles of hip, knee and ankle joints during standing,	
	QMAS and HMAS between control group and	
	NMES group for pre-training	
3.	Comparisons of normalized QMVIC, quadriceps lag,	48
	angles of hip, knee and ankle joints during standing,	

QMAS and HMAS between groups and within each group

ix

4.	Comparisons of percent changes in QMVIC	52
	between groups and within each group	
CHAPTER V D	ISCUSSION	
1.	Discussion	54
2.	Conclusion	61
3.	Clinical application	62
4.	Limitation and future study	63
REFERENCES		64
APPENDICES		

APPENDIX A Gross motor function classification system	72
APPENDIX B Popliteal angle test	75
APPENDIX C Modified Ashworth Scale	76
APPENDIX D Modified chair	77
APPENDIX E Reliability of the study	78
APPENDIX F Participant's information form	80
APPENDIX G Consent form 1	82
APPENDIX H Consent form 2	83
APPENDIX I Certificate of ethical clearance	85
APPENDIX J Current amplitude sheet form	86
CURRICULUM VITAE	

Х

LIST OF TABLES

Tab	ble	Page
1	Parameters for electrical stimulation in general clinical application	25
2	Stimulation parameters used in the study of Daichman and co-workers	28
3	Stimulation parameters used in the study of Kerr and co-workers	30
4	Stimulation parameters used in the present study	41
5	The demographic characteristics of the participants	46
6	Comparisons of normalized QMVIC, quadriceps lag,	48
	angles of hip, knee and ankle joints during standing, QMAS and HMAS	
	between control group and NMES group for pre-training	
7	Comparisons of normalized QMVIC, quadriceps lag,	51
	angles of hip, knee and ankle joints during standing,	
	QMAS and HMAS between groups for each test time	
	and between test times for each group	
8	Comparisons of percent changes in QMVIC between groups	53
	and within each group	
9	The demographic characteristics of children with spastic diplegia	78
10	The intraclass correlation coefficients (ICC $_{(3,k)}$) of QMVIC,	79
	quadriceps lag, QMAS, HMAS and angles of hip, knee and ankle joints	
	during standing	

xi

LIST OF FIGURES

Fig	ure	Page
1	Children with spastic diplegia, hemiplegia and quadriplegia	7
2	Children with spastic diplegia walk with crouch gait	7
3	Average joint kinematics for typically developing children	9
	and children with CP who walk with crouch gait (knee flexion)	
4	Average joint kinematics for typically developing children	9
	and children with CP who walk with crouch gait (hip flexion)	
5	Average joint kinematics for typically developing children	9
	and children with CP who walk with crouch gait (ankle dorsiflexion)	
6	Percent normalized quadriceps strength in children with CP with	13
	respect to knee joint angle during sitting	
7	Relative roles of neural and muscular adaptations in strength	16
	improvement with resistance exercise training	
8	The assessment and the weeks of NMES training	34
9	Position of participant for assessment quadriceps and	37
	hamstrings muscle spasticity	
10	Position of participant for assessment quadriceps lag	38
11	Position of participant for assessment hip, knee and ankle	39
	joints angles during standing	
12	Position of participant for assessment QMVIC	40
13	Position of participant for quadriceps strength training	42

14	Diagram of experimental procedure	43
15	Profile plot for interaction effect between time x group of	49
	normalized QMVIC	
16	Profile plot for interaction effect between time x group of	49
	quadriceps lag	
17	Profile plot for interaction effect between time x group of	52
	percent changes in QMVIC	
18	GMFCS levels in the 6-12 years	73
19	GMFCS levels in the 12-18 years	74
20	Popliteal angle test	75
21	Modified chair for quadriceps strength training and assessment QMVIC	77

ABBREVIATIONS

СР	Cerebral palsy
0	Degree
ES	Electrical stimulation
FES	Functional electrical stimulation
GMFCS	Gross motor function classification system
GMFM	Gross motor function measure
HHD	Hand held dynamometer
HMAS	Hamstrings modified Ashworth scale
kg	Kilogram
LAQ	Lifestyle assessment questionnaire
MAS	modified Ashworth scale
μs	Microsecond
mA	Miiliampere
Max	Maximum
Min	Minimum
ms	Millisecond
MMT	Manual muscle test
MVIC	Maximum voluntary isometric contraction
Ν	Number of participants
n	Number of legs

xiv

NMES	Neuromuscular electrical stimulation
PEDI	Pediatric evaluation of disability inventory
0⁄0	Percentage
pps	Pulses per second
QMAS	Quadriceps modified Ashworth scale
QMVIC	Quadriceps maximum voluntary isometric contraction
ROM	Range of motion
S	Second
SD	Standard deviation
TES	Threshold electrical stimulation
TD	Typical development
VS	Versus
yr	Year