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Sense of effort associated with exercise in the chronic fatigue syndrome

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SENSE OF EFFORT ASSOCIATED WITH EXERCISE IN THE CHRONIC FATIGUE SYNDROME

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ABSTRACT

Investigations into the mediators of effort sensation have indicated that central mechanisms related to corollary discharges may be responsible for an increased sense of effort during fatiguing isometric exercise. The role for central mediators for sense of effort have been objectively demonstrated through use of contralateral limb matching tasks. Subjects diagnosed with chronic fatigue syndrome (CFS) often report prevalent fatigue associated with a greater sense of effort when involved in exercise. This study employed a fatiguing contralateral limb-matching task in order to determine if CFS subjects (n = 6) experienced an altered sense of effort associated with the task when compared to control group (n = 6). The task involved subjects performing an intermittent sub-maximal contraction in their reference (non-dominant) arm for a 45 minute period. Subjects attempted to match the force in their reference arm (30% MVC) with their dominant arm every minute, except for every fifth minute, when a maximal voluntary contraction (MVC) was performed in the reference arm. Associated electromyography (EMG), force, and rate of perceived exertion (RPE) were recorded on a regular basis. Results indicated that while there were no significant difference between groups for matching force, rmsEMG amplitude, and MVC force, there was a significant difference in reported RPE scores ($P < 0.05$) during the fatiguing task, as well as during baseline measurements. Elevated RPE scores, combined with trends indicating that a longer protocol may have produced a significant difference in matching force, provide evidence demonstrating that CFS subjects experienced a greater sense of effort relative to controls. This study demonstrates that the symptom of fatigue experienced in CFS may be better defined employing mediators for sense of effort than the regular application of a neurophysiological definition of fatigue concerned with the loss of force generating capacity.

Table Of Contents

		Page Number
Declaration		iii
Acknowledgments		iv
Abstract		v
Table of Contents		vi
List of Figures		viii
List of Tables		ix
Abbreviations		xi
Definitions of Important Terms		xii
CHAPTER		
1.0	Introduction	1
	1.1 Background to Study	1
	1.2 Purpose of Study	3
	1.3 Aims of Study	3
	1.4 Research Questions	4
	1.5 Hypotheses	5
2.0	Literature Review	5
	2.1 Introduction	5
	2.2 Sense of Effort	5
	2.3 Perceived Exertion	9
	2.4 Global Perspective of Sense of Effort	10
	2.5 Quantifying Sense of Effort	10
	2.6 Definition and Aetiology of CFS	11
	2.7 Fatigue in CFS	12
	2.8 Sense of Effort in CFS	13
	2.9 Conclusion	14
3.0	Method	15
	3.1 Subject Details	15
	3.1.1 CFS Subjects	16
	3.1.2 Control Subjects	16
	3.2 Equipment	18
	3.2.1 Calibration Procedure	19
	3.3 Recording and Analysis of Electromyography (EMG)	20
	3.4 Determination of Maximal Voluntary Contraction and Recording of Force Data	21
	3.5 CR-10 Scale	21
	3.6 Pilot Study	22
	3.7 Study Design	22
	3.7.1 Baseline Measurements	22

3.7.2 Fatiguing Task 23
3.7.3 Recovery Protocol 23
3.8 Data and Statistical Analysis 24
3.8.1 Data Analysis of Pilot Study Results 24
3.8.2 Data and Statistical Analysis of Baseline Measurements 24
3.8.3 Data and Statistical Analysis of Results Recorded During the Fatiguing Task 25
3.8.4 Data and Statistical Analysis of Results Recorded During Recovery 26
3.9 Delimitations and Limitations 26
3.9.1 Subject Delimitations 26
3.9.2 Subject Limitations 26
3.9.3 Research Limitations 27

4.0 Results 28

4.1 Pilot Study 28
4.2 Results for Baseline Measurements Made Prior to Fatiguing Task 31
4.2.1 POMS Results for CFS and Control Groups 31
4.2.2 MVC Force Results for CFS and Control Groups 32
4.2.3 MVC rmsEMG Results for CFS and Control Groups 33
4.2.4 Matching Force Values for Sub-Maximal Contractions 34
4.2.5 Matching rmsEMG Values for Sub-Maximal Contractions 35
4.2.6 RPE Responses During Sub-Maximal Contractions 36
4.3 Fatiguing Task 37
4.3.1 MVC Force Results During the Fatiguing Task 37
4.3.2 MVC rmsEMG During the Fatiguing Task 38
4.3.3 Matching Force During the Fatiguing Task 39
4.3.4 Matching rmsEMG During the Fatiguing Task 40
4.3.5 Reference rmsEMG During the Fatiguing Task 41
4.3.6 Correlation Between Matching Force and Reference rmsEMG Results During the Fatiguing Task 42
4.3.7 RPE During the Fatiguing task 44
4.4 Recovery 46
4.4.1 Matching Force During Recovery for CFS and Control Groups 46
4.4.2 Matching rmsEMG During Recovery for CFS and Control Groups 47
4.4.3 Reference rmsEMG During Recovery for CFS and Control Groups 48
4.4.4 MVC Force Data During Recovery for CFS and Control Groups 49
4.4.5 MVC rmsEMG During Recovery for CFS and Control Groups 50

5.0 Discussion 52

5.1 Introduction 52
5.2 Central Fatigue and Sense of Effort 52
5.3 Matching Force Production During the Fatiguing Task 54

5.4	Reference rmsEMG Amplitude During the Fatiguing Task	55
5.5	Sense of Effort During the Fatiguing Task	57
5.6	Conclusion	61

References 64

Appendices

A	Criteria for CFS Diagnosis	72
B	Consent Form	74
C	Activity Sheet	76
D	Medical Questionnaire	79
E	POMS Questionnaire	83
F	Calibration Details	85
G	RPE Data Collection Sheet	87
H	CR-10 Scale	89
I	Raw Data For Pilot Study	91
J	Raw and Normalised Data for Formal Testing	97

List of Figures

Page Number

Figure 3.1	Photograph of equipment used during pilot study and formal testing	18
Figure 3.2	Front view of a subject restrained in the force chair prior to testing.	19
Figure 3.3	Photograph demonstrating the placement of EMG electrodes on subjects Arm.	20
Figure 4.1	Test-retest correlation for MVC during pilot study	
Figure 4.2	Test-retest correlation for MVC rmsEMG during pilot study	29
Figure 4.3	Test-retest results for MVC to rmsEMG during pilot study	30
Figure 4.4	MVC force values	32
Figure 4.5	MVC rmsEMG values	33
Figure 4.6	Matching force for sub-maximal contractions	34
Figure 4.7	Matching rmsEMG for sub-maximal contractions	35
Figure 4.8	RPE values for sub-maximal contractions in reference arm	36
Figure 4.9	MVC force during the fatiguing task	37
Figure 4.10	MVC rmsEMG during the fatiguing task	38
Figure 4.11	Matching force during the fatiguing task	39
Figure 4.12	Matching rmsEMG during the fatiguing task	40
Figure 4.13	Reference rmsEMG during the fatiguing task	41
Figure 4.14	Correlation of normalised reference rmsEMG and matching force	43
Figure 4.15	RPE Data during the fatiguing task	45
Figure 4.16	Recovery MVC force	49
Figure 4.17	Recovery MVC rmsEMG	51

List of Tables

		Page Number
Table 3.1	Subject particulars	17
Table 4.1	CFS and control subjects' T scores for specific psychological variables measured in POMS questionnaire	31
Table 4.2	Mean results for normalised matching force for the CFS and control groups recorded at 1, 3, 5, and 10 minutes during the recovery protocol	46
Table 4.3	Mean results for normalised matching rmsEMG for the CFS and control groups recorded at 1, 3, 5, and 10 minutes during the recovery protocol	47
Table 4.4	Mean results for normalised reference rmsEMG for the CFS and control groups recorded at 1, 3, 5, and 10 minutes during the recovery protocol.	48

Abbreviations

ANOVA	Analysis of variance (statistical test)
CFS	Chronic fatigue syndrome
CNS	Central nervous system
EMG	Electromyography
MVC	Maximal voluntary contraction(s)
POMS	Profile of moods states
rmsEMG	Root mean squared electromyography
RPE	Rate of perceived exertion
SEM	Standard error of the mean
URTI	Upper respiratory tract infection

Definitions for Important Terms

Central fatigue:	Impaired motivation or failure of the motoneurone drive (Stokes, Edwards & Cooper, 1989).
Central mediators for 'perceived exertion':	Mediators of pulmonary ventilation and circulation such as heart rate, ventilatory volume, and respiration rate (Mihevic, 1981).
Central mediators for 'sense of effort':	The amplitude of the corollary discharge of the descending motor command. (Jones, 1995).
Chronic fatigue syndrome:	Debilitating disorder characterised by the new onset of profound physical and mental fatigue that lasts for more than 6 months and is serious enough to reduce activity by more than half (Sisto et al. 1996).
Corollary discharge:	Copy of efferent motor command sent to the sensory cortex (Also called efferent feedforward signal) (Jones, 1995).
Efferent feedforward signal:	See corollary discharge.
Fatigue:	A decrease in force generating capacity (Lewis & Haller, 1991).

Matching arm	Dominant arm
Maximal voluntary contraction(s):	The most force that a muscle group or muscle can produced in a given position (Cafarelli, 1988).
Perceived exertion:	Sensations arising from indicators that act individually or collectively to alter tension producing properties of skeletal muscle (Noble & Robertson, 1996).
Peripheral mediators for 'perceived exertion':	Afferent input from the musculature such as H+ ions, Golgi tendon organ activity and general muscle sensation (Mihevic, 1981).
Peripheral mediators for 'sense of effort':	Signals from peripheral receptors located in the skin, joints and muscles that are presumed to provide a measure of actual force exerted (Cafarelli, 1988).
Sense of effort:	The act of determining and interpreting sensations arising from the body during activity (Noble & Robertson, 1996
Reference arm	Non –dominant arm

CHAPTER ONE

INTRODUCTION

1.1 Background To Study

Most of us at some time or another have been involved in an activity and experienced an increasing sense of effort as time passes. The child we are holding begins to feel like a dead weight; the brief case could serve as an anchor; while the five-kilometre jog, which began with a spring in the step ends with legs that feel like lead, coupled with a respiration rate that alarms onlookers. It is on the basis of these feelings that decisions are made as to whether or not the activity will continue at the same pace, slow down or even come to an abrupt halt. The ability to sustain a desired pace or even to continue an activity is crucial for the competitive athlete. For the sports scientist and clinician, an understanding of the factors that constitute this sense of effort will assist in the designing of effective exercise and rehabilitation programs.

Study of the primary mediators in effort sensation is particularly pertinent to those people who suffer from 'effort syndromes' such as chronic fatigue syndrome (CFS). CFS represents a debilitating disorder that is characterised by severe mental and physical fatigue (Edwards, 1992). Often the fatigue reported by people with CFS is associated with an increased sense of effort when performing exercise and everyday tasks (Lawrie, McHale, Power & Goodwin, 1997). Application of a neurophysiological definition to the term fatigue (i.e. loss of force generating capacity), has allowed investigators to explore the symptom of fatigue reported by CFS subjects from a peripheral and/or central perspective. While results have been equivocal, the majority of studies have demonstrated normal

muscle physiology in CFS subjects, implying a central basis for fatigue (Jamel & Miller, 1991; Lloyd, Gandevia & Hales, 1991; Wessely & Edwards, 1993).

Further research into the symptom of fatigue experienced by people with CFS is provided by mediators that contribute to sense of effort. According to McCloskey (1978), Jones and Hunter (1983a), and Cafarelli (1988), employment of a contralateral limb matching task during a fatiguing exercise, provides objective measurement of sense of effort. This task demonstrates that as fatigue develops, attempts to match a low-level isometric force held in the reference limb tend to be overestimated by the contralateral limb. Overestimation of the reference force indicates attention to central mediators for effort sense rather than the actual force (Jones, 1995). Employment of a contralateral limb matching paradigm during a fatiguing, sub-maximal, isometric task is ideally suited for investigating whether CFS subjects associate a given task with a greater sense of effort, when compared to healthy controls. If CFS subjects consequently report a greater sense of effort, then this may imply a relationship between the fatigue experienced by people with CFS and central mediators for sense of effort.

CFS represents a debilitating disorder that is poorly understood. Currently there is a lack of consensus regarding the basis of the fatigue symptoms that typify the disorder, while controversy surrounds the aetiology of the disease. Investigation into the sense of effort experienced by CFS sufferers may lead to a better understanding of the disorder, as well as provide the basis for a quantitative measure for the perception of fatigue. This would be useful in assessing the severity of the condition, as well as for monitoring progress over time.

1.2 Purpose of Study

The purpose of this study is to determine whether an exercise paradigm consisting of intermittent sub-maximal and maximal isometric contractions of the elbow flexors is associated with an abnormal strength decline and a greater sense of effort in CFS subjects, when compared to healthy control subjects. This will assist in determining whether altered muscle function and/or an altered sense of effort play a role in the poor exercise tolerance displayed by CFS subjects.

1.3 Aims of Study

The aims of this study are:

1 To determine whether CFS subjects have a percentage strength loss similar to controls when performing intermittent MVC during a fatiguing task.

2 To determine whether CFS subjects have an altered sense of effort associated with a fatiguing task.

1.4 Research Questions

This study addresses the following research questions:

1 Will CFS subjects show the same decline in maximum force during a fatiguing exercise, when compared to control subjects?

2 Will CFS subjects exhibit altered force production in their matching limb during a contralateral limb matching task employing a fatiguing exercise, when compared to control subjects?

3 Will CFS subjects demonstrate altered reference rmsEMG activity during a fatiguing exercise, when compared to control subjects?

4 Will CFS subjects report higher levels of perceived exertion during a fatiguing exercise, when compared to control subjects?

1.5 Hypotheses

It is hypothesised that while performing a fatiguing exercise, the following outcomes will occur:

1 CFS subjects will show a greater decline in maximal force over time, when compared to control subjects.

2 CFS subjects will exhibit increased force production of the matching limb in a contralateral limb matching task over time, when compared to control subjects.

3 CFS subjects will demonstrate greater reference rmsEMG amplitude over time, when compared to control subjects.

4 CFS subjects will report higher levels of perceived exertion over time, as measured on the CR-10 scale, when compared to control subjects.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The significance of effort perception is not only of interest to the athlete, sports scientist and clinician, but also to patients diagnosed with effort or fatigue syndromes such as CFS. This review will consider the history related to sense of effort research, as well as related studies pertaining to perceived exertion. The evolution of a global approach to sense of effort will be described along with popular methods related to its quantification. Finally, the relationship between sense of effort and the fatigue reported by people with CFS will be addressed.

2.2 Sense of Effort

Sense of effort is defined by Noble and Robertson (1996, p. 4) as "consisting of the act of determining and interpreting sensations arising from the body during activity." The search to understand the mediators that give rise to a sense of effort, or what has traditionally been called kinesthetic sensibility, has interested researchers for more than a century. Diversity in opinion resulted in the emergence of two perspectives regarding the dominant cues for effort sense, with contention still existing today.

The first perspective emerged early in the nineteenth century when Bell (1826, cited in McCloskey, 1981), postulated that kinesthetic sensibility was based on the conscious awareness of information received through proprioception. Proprioception, which

describes perceptions of position, force and movement (Jones, 1994), is determined by afferent information signalled to the central nervous system (CNS) from peripheral indicators located in the skin, joints and muscles (Voight, Hardin, Blackburn, Tippett, & Canner, 1996). According to Cafarelli (1992), peripheral indicators are represented by Golgi tendon organs, muscle spindles, skin receptors, muscle receptors embedded in joint capsules, and small unmylinated polymodal 'c' fibres. Cafarelli (1992) further notes that information pertaining to muscle length and tension are signalled by spindle afferents and Golgi tendon organs, thereby providing proprioceptive information related to position, velocity, and force, while muscle and skin receptors provide information associated with pressure, temperature, and the intramuscular concentration of certain ions.

In contrast to Bell's view, Helmholtz (1866, cited in Cafarelli, 1988) suggested that sensations giving rise to a 'force of will' were centrally generated, and arose from innervation of the efferent pathway without the benefit of feedback from peripheral receptors. Bell's original theory however, continued to be supported in the early 1900's by Sherrington, who again emphasised peripheral organs and afferent nerves as the primary source for effort sensation (McCloskey, 1981). Jones (1986) notes that this view was held uncontested for over 50 years until experiments by Sperry demonstrated that internal signals arising from motor commands did indeed influence perception. Sperry (1950, cited in McCloskey, Gandevia, Potter & Colebatch, 1983), later coined the term corollary discharge to describe this phenomenon. According to McCloskey, Ebeling, and Goodwin (1974), Sperry's work coupled with that by Van Holst and Mittelstoedt, resulted in a shift from the predominant belief that peripheral mediators were the primary cue in determining sense of effort, to the recognition of the role of centrally generated efferent commands.

The importance of centrally generated efferent signals in determining sense of effort is exemplified in contralateral limb matching tasks, which have been employed to investigate the cues for effort associated with sustained sub-maximal isometric contractions (Cafarelli, 1988; Jones, 1995; McCloskey, 1978). During these tasks, a sustained constant force contraction is matched in subjective magnitude by contraction of the contralateral limb. McCloskey (1978) notes that a contralateral limb matching task provides an objective indicator for perceived heaviness, as changes in effort sensation are reflected by the match of the non-reference limb. Results have consistently demonstrated that as fatigue develops, subjects tend to overestimate the force when attempting to match a sustained isometric contraction of the reference arm. According to many investigators (Aniss, Gandevia & Milne, 1988; Cafarelli, 1992; Gandevia, 1997; McCloskey, 1978), this overestimation in judgement of reference force indicates the magnitude of the efferent signal as the dominant cue for effort sensation. An increase in the efferent signal is further supported by surface EMG recordings. According to Cafarelli and Layton-Wood (1986), average surface EMG is representative of the summation of action potentials present in individual motor units. Maton (1981) notes that average surface EMG increases steadily with fatigue during sub-maximal contractions. This increased activity indirectly reflects the magnitude of the descending motor command needed to recruit additional motor units in order to compensate for the partial failure of those already recruited (Bigland-Ritchie 1981; Maton, 1981).

Studies that demonstrate changes in perceived force, when actual force remains constant, form the cornerstone for arguments that the CNS incorporates central mediators in judgements of force and heaviness (Gandevia, 1997). Other studies however, have indicated a role for peripheral mediators. The involvement of peripheral mediators in effort sense has been demonstrated in studies where some subjects were able to accurately

estimate the force in their reference arm with their matching arm. Accurate estimation of reference force by some subjects, have been demonstrated in studies where the reference arm was subject to gallamine-induced paresis (Jones & Hunter, 1983b) or vibration of the agonist muscle (McCloskey et al. 1974). According to Jones (1983), accurate estimation of force in the reference arm indicates attention to afferent feedback, in particular signals arising from Golgi tendon organs. McCloskey et al. (1974) note that attention to feedback from afferent sources provides a sense of force or tension, while attention to centrally generated efferent commands (corollary discharges) gives rise to a sense of effort.

Further studies by Cafarelli (1988), Jones (1995), and Lawrie et al. (1997), emphasised a complementary rather than an exclusive role for peripheral and central mediators in producing effort sensation. This interactive role is described by Cafarelli (1988), who suggests that purposeful activity, which is largely initiated from the motor cortex, descends through the spinal cord impinging on the motor neuron pool. According to Cafarelli (1988, p. 140) "a copy of the central signal probably irradiates to the cardiovascular and respiratory centres in order to invoke anticipatory activation of those systems." Indirect evidence suggests that a copy of the motor outflow (corollary discharge) is fed forward to the sensory cortex, presetting it for anticipated consequences of the motor output (Jones, 1995). According to Jones (1995), afferent inflow from peripheral receptors is compared to the copy of the motor outflow and under normal conditions sensory signals arising from peripheral and central indicators are highly correlated. When this relationship is altered, as can occur during fatigue, partial curarisation, hemiparesis and cerebellar lesions without sensory loss, the motor signal is forced to recalibrate (Cafarelli, 1988; Jones, 1995). This recalibration creates a change in the amplitude of the corollary discharge, which reflects the

magnitude of the voluntary motor commands generated, as well as the effort sensed (Lawrie et al. 1997).

2.3 Perceived Exertion

While sense of effort was explored by various researchers from a neurophysiological perspective, studies by Ekblom and Goldbarg (1971) involved a more specific analysis of the mediators that determine 'perceived exertion'. Perceived exertion differs from the traditional concept of sense of effort in that it represents a psychophysiological view of indicators that "act individually or collectively to alter tension producing properties of skeletal muscle" (Noble & Robertson, 1996, p. 105). Literature pertaining to perceived exertion categorises these indicators as having either a local (peripheral) or central basis.

Local indicators that give rise to perceived exertion are based on those factors that mediate feelings of strain in the exercising muscle (Borg, 1982; Ekblom & Goldbarg, 1971), and include "muscle lactate, Golgi tendon organ activity and general muscle sensation" (Mihevic, 1981, p. 155). Central indicators of perceived exertion are represented by pulmonary ventilation and circulation mediators, which include heart rate, ventilatory minute volume, respiration rate and oxygen consumption (Mihevic, 1981).

Just as research in the neurophysiological field has focused on identifying the dominant signal in effort sensation, investigators involved in psychophysiological studies of perceived exertion have pursued the same objective. Early studies by Ekblom and Goldbarg (1971) involving dynamic exercise, proposed that local factors were dominant in work that incorporated the use of small muscles, while work involving large muscle groups stressed central mediators of the cardiopulmonary and respiratory system. Later studies

incorporating dynamic exercise, demonstrated the importance of exercise duration. Robertson (1982) noted that during short term work, perception of exertion originating in the skin, muscles and joints (local cues) gave rise to sensations of force and rate of contraction, while sensations from the organs of circulation and respiration (central cues) became important during prolonged work. Robertson (1982, p. 390) concluded that local factors were assumed to provide the primary sensory signals, while "central factors act as an amplifier or gain modifier that potentiate the local signals in proportion to the aerobic demand".

2.4 Global Perspective of Sense of Effort

According to Noble and Robertson (1996), a contemporary model for sense of effort is represented by the integration of psychophysiological and neurophysiological mediators. These authors continue to suggest that changes in peripheral and respiratory (central) muscle tension "are monitored through a final common neurophysiological pathway that transmits exertional signals from the motor to the sensory cortex" (p. 105). The integration of these signals, with psychological and performance mediators, is consciously interpreted by the sensory cortex, resulting in a global sense of effort (Noble & Robertson, 1996). While multiple signals contribute to a global sense of effort, the dominant signal will depend on exercise duration, levels of force, and whether exercise is dynamic or static (Cafarelli, 1982; Robertson, 1982).

2.5 Quantifying Sense of Effort

Contemporary methods for quantifying sense of effort evolved from early research concerned with measuring perceived exertion. In the early 1960's, Borg produced a 21 point ranked order category scale designed to quantify perceived exertion (Mihevic, 1981).

In order to address inherent problems, this scale was later modified resulting in a 15 point scale known as the 'Borg' or 'RPE' (rate of perceived exertion) scale, which was based on heart rate values achieved during graded exercise on a cycle ergometer (Borg, 1982). In response to criticism that this modified scale did not posses ratio properties, Borg developed the CR-10 scale (Cafarelli, 1988). The CR-10 scale consists of numbers ranging from 0 to 10 which correspond to various verbal descriptions that rate the perceived effort from 'nothing at all" to "very, very hard" (Suminski et al. 1997). When using this scale, subjects are permitted to go beyond the number 10, as well as include decimal points (Borg, 1982).

While the scales devised by Borg were designed to measure perceived exertion as defined by psychophysiological mediators, the very nature of the scales, which require subjects to rate how they feel during an exercise, encompass all factors that contribute to a global sense of effort. These factors include neurophysiological and psychological mediators, as well as performance milieu if ratings are taken during competition (Hassmen, 1996). The all-inclusive nature of these scales make them valuable tools in quantifying global sense of effort.

2.6 Definition and Aetiology of CFS

Stokes, Edwards, and Cooper (1989) note that the significance of effort perception is particularly pertinent to patients with effort or fatigue syndromes. CFS represents a multifaceted disorder that is characterised by the new onset of profound physical and mental fatigue "that lasts for more than 6 months and is serious enough to reduce activity by more than 50%" (Sisto et al. 1996). Diagnosis is based on the fulfilment of two major

criteria, as well as 8 of 11 minor criteria (detailed in Appendix A) (Manu, Lane & Matthews, 1992; Jain & DeLisa, 1998).

The aetiology of CFS is characterised by speculation and controversy. Common suggestions for causative agents include psychological factors (Hickie, Lloyd & Wakefield, 1995; Woods & Goldberg, 1991), viral infection (Lewis, Cooper & Bennett, 1994), immunological abnormalities (Cunningham, Bowles & Archard, 1991; Lloyd, 1990), pathophysiological changes in skeletal muscle (Edwards, Newham & Peters, 1991), metabolic dysfunction (Kennedy, 1991), neuromuscular dysfunction (Jamal & Miller, 1991), as well as neuroendocrine abnormalities with particular emphasis on hypothalamic-pituitary-adrenal axis dysfunction (Bearn & Wessely, 1994; Behan & Bakheit, 1991). Difficulty in assigning a particular aetiology to CFS is attributed to evidence that suggests that many symptoms experienced by CFS subjects are not consistent, can occur in normal subjects, and may reflect secondary changes as a result of reduced activity and consequent deconditioning (Edwards, Clague, Gibson & Helliwell, 1994).

2.7 Fatigue in CFS

CFS subjects regularly report the presence of profound physical and mental fatigue which can be present at rest and exacerbated by exercise (Edwards, 1984; Gibson, Carroll, Clauge & Edwards, 1993). Defining fatigue represents a challenging task, as the definition will differ depending on the perspective adopted (Barofsky & Legro, 1991; Petajan, 1996). An objective and commonly used approach is offered by a neurophysiological perspective, which defines fatigue as a decrease in force generating capacity (Lewis & Haller, 1991). This definition also assists in narrowing the origin of the complaint as it recognises that fatigue can occur due to impairment at any site in the chain of command for muscle

activation, from the higher cortical centres to the interaction of actin and myosin. This allows fatigue to be further classified as having either a peripheral or central basis (Edwards et al. 1994). Stokes, Cooper and Edwards (1988, p. 278) define central fatigue by "impaired motivation or failure of motoneurone drive." Central fatigue may arise as a result of pathological processes, fear of pain, decreased motivation, impaired concentration (Kent-Braun, Sharma, Weiner, Massie & Miller, 1993), low blood sugar (Jones & Round, 1995), apprehension (Gibson et al. 1993), as well as intolerance of the discomfort associated with fatiguing exercise (Lewis & Haller, 1991). Peripheral fatigue is associated with various processes concerned with the propagation of muscle action potential or generation of force within the muscle fibre (Jones & Round, 1995). These processes which include metabolic depletion, accumulation of metabolites or damage (Jones & Round, 1995), may result in impairment to neuromuscular transmission, sarcolemma excitation or excitation-contraction coupling (Edwards et al. 1991; Wessely & Edwards, 1993).

Many studies which have investigated muscular fatigue in CFS suggest a strong central component (Bearn & Wessely, 1994; Kent-Braun et al. 1993; McCully, Sisto & Natelson, 1996). Support for a central basis for fatigue in CFS is provided by studies that demonstrate normal peripheral neuromuscular function (Kent-Braun et al. 1993; Jamel & Miller, 1991; Lloyd, Hales & Gandevia, 1988), as well studies that demonstrate an inability by some CFS subjects to fully activate skeletal muscle during intense sustained exercise (Kent-Braun et al. 1993; Stokes et al. 1989). Evidence for histochemical abnormalities in the skeletal muscles of some CFS patients are generally not considered significant and often reflect deconditioning (Edwards et al. 1994; McComas, Miller & Gandevia, 1996).

2.8 Sense of Effort in CFS

Subjects with CFS often describe an increased sense of effort associated with exercise when compared to healthy subjects (Edwards, 1992; Lloyd & Pender, 1994; Miller, Allen, Gandevia, 1996; Wessely & Edwards, 1993). Abnormal effort sensation in CFS subjects has been demonstrated after peak treadmill exercise (Riley, O'Brien, McCluskey, Bell & Nicholls, 1990), absolute workloads of incremental treadmill exercises (Sisto et al. 1996), and during sub-maximal and maximal isometric contractions (Brouwer & Packer, 1994; Kent-Braun et al. 1993). Gibson et al. (1993) further demonstrated an abnormal sense of effort in CFS subjects during an incremental cycle ergometer test. In contrast to these studies, Lloyd et al. (1991, p. 96) demonstrated no difference in effort sensation for repetitive sub-maximal contractions between CFS and control subjects.

2.9 Conclusion

While many studies have demonstrated that CFS subjects rate the effort associated with a comparable exercise higher than healthy subjects, "suggesting an increased 'gain' in the perception of physiological signals" (Edwards et al. 1991, p. 834), results have been equivocal. To date there have been no studies that have utilised a contralateral limb matching task in order to investigate fatigue and effort perception responses in CFS subjects. Employment of such a tool will provide a more objective indicator of sense of effort in CFS subjects, and may indicate an association between mediators for sense of effort and the symptom of fatigue reported by CFS patients. If such an association can be established, then this may imply a central basis for the fatigue experience in CFS. Refining the nature of fatigue experienced in CFS will assist in defining the aetiology of the disorder, as well as determining the effectiveness of any therapeutic intervention.

CHAPTER THREE

METHOD

3.1 Subject Details

This study consisted of a control and a CFS group, with six subjects in each group who met selected criteria (detailed in sections 3.1.1 and 3.1.2). Subject details are contained in Table 3.1. Subjects were informed of all procedures and completed the following forms prior to testing:

Consent form:	Described the purpose of the study, the associated protocol as well as possible side effects from the exercise (Appendix B).
Activity Questionnaire:	Based on a model by Sharkey (1991), and designed to determine subject's activity level (Appendix C).
Medical Questionnaire:	Designed to screen for medical or neuromuscular conditions that could exclude potential subjects from the study (Appendix D).
Profile of Mood States (POMS) Questionnaire:	A 65 five-point adjective rating scale designed to assess each subject's mood state at the time of testing (Appendix E).

Subjects were informed that they were free to withdraw from the study at any time without prejudice. Ethical approval had been granted for this study by the Edith Cowan University Ethics Committee prior to testing.

3.1.1 CFS Subjects

Subjects were recruited from QEII Medical Centre, general practitioners and from the CFS Support Association. Subjects consisted of 4 males and 2 females, medically diagnosed as suffering from CFS triggered by an infectious episode, and contracted in the last 6 months to 3 years. Relevant clinical details are contained in Table 3.1. Values (mean ± SD) for age, weight, and height were 36.6 ± 16.2 years, 84.0 ± 21.1 kg, and 179.1 ± 12.2 cm respectively. Activity levels ranged from sedentary to highly active, while all subjects were right hand dominant.

3.1.2 Control Subjects

The control group consisted of 4 males and 2 females recruited from friends and colleagues of the investigator, as well as from the university population. Subjects were selected on the basis of being matched to CFS subjects according to their activity level (as determined by an activity questionnaire), as well as by their gender, age, weight, and height. Values (mean ± SD) for age, weight, and height were 37.3 ± 15.8 years, 83.0 ± 15.7 kg, and 176.5 ± 8.5 cm respectively. While one subject was noted to be ambidextrous, all reported as right hand preferred.

Table 3.1

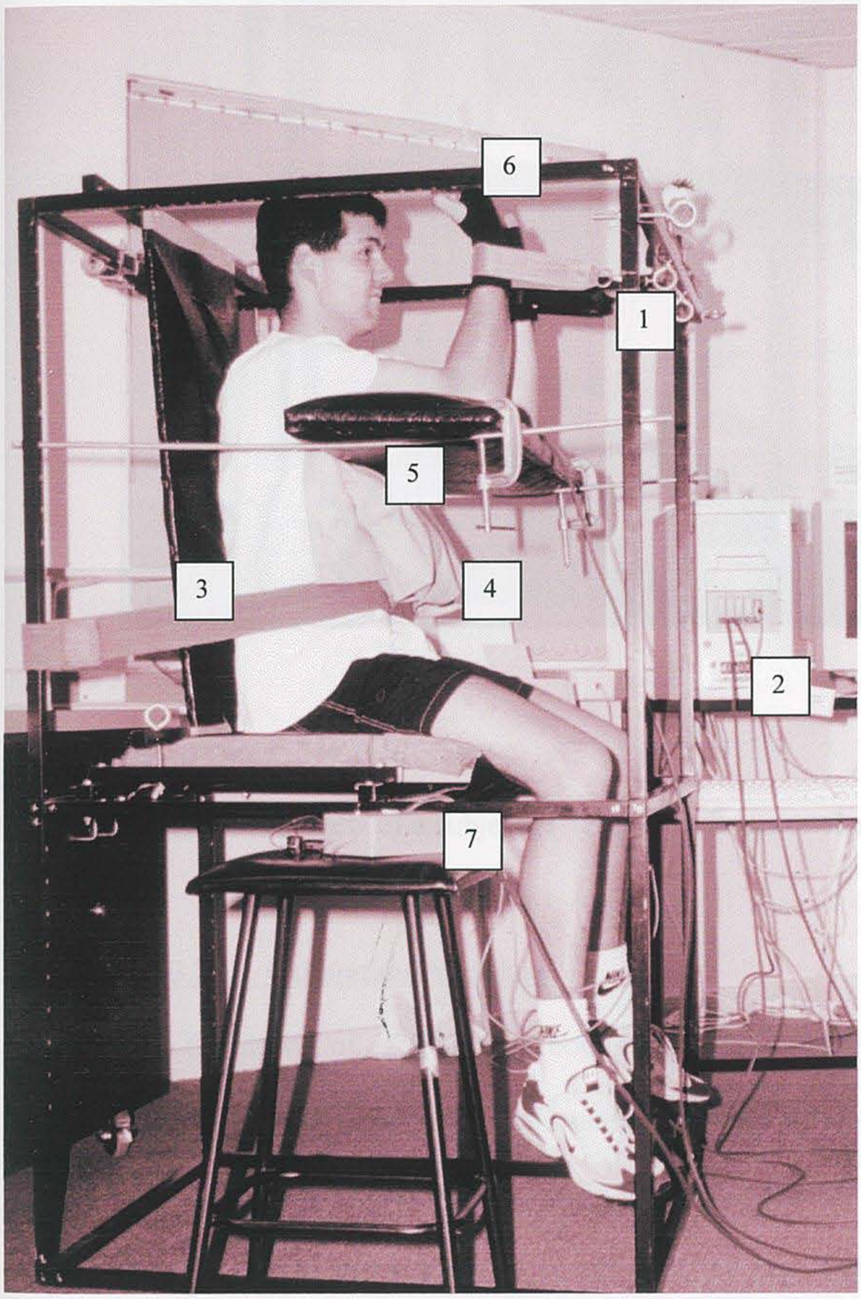
Subject Particulars

Subjects	Gender	Age (yrs)	Weight (kg)	Height (cm)	Activity level	Presenting infection and time since diagnosed with CFS
Control No 1	Female	39	60	167	Moderate	
CFS No 1	Female	37	61	164	Moderate	URTI* 24 months
Control No 2	Female	25	85	170	Moderate	
CFS No 2	Female	24	80	169	Moderate	Gastroenteritis 9 months
Control No 3	Male	25	75	178	Highly Active	
CFS No 3	Male	23	68	178	Highly Active	URTI 10 months
Control No 4	Male	61	86	172	Moderate	
CFS No 4	Male	58	80	178	Moderate	URTI 32 months
Control No 5	Male	51	108	182	Sedentary	
CFS No 5	Male	55	120	189	Sedentary	Glandular Fever 15 months
Control No 6	Male	23	84	190	Highly Active	
CFS No 6	Male	23	95	197	Highly Active	Glandular Fever 18 months

* Upper Respiratory Tract Infection

3.2 Equipment

Equipment used during the pilot study and formal testing session are listed below and featured in Figures 3.1 and 3.2.



1 Tensiometer strain gauge
2 IBM Processor
3 Force chair with restraining straps
4 Chest pad
5 Padded board & C-clamps
6 Wrist protectors
7 5 Volt power supply & batteries
- Surface EMG electrodes Ag/AgCI, Meditrace (approx 1 sq cm in size)
- CR-10 Scale
- Tape recorder and tape
- Excel and SPSS software
- Cotton wool
- Alcohol swabs

Figure 3.1 Photograph of equipment used during the pilot study and formal testing. Photograph illustrates side on view of a subject restrained in the force chair in preparation of testing.

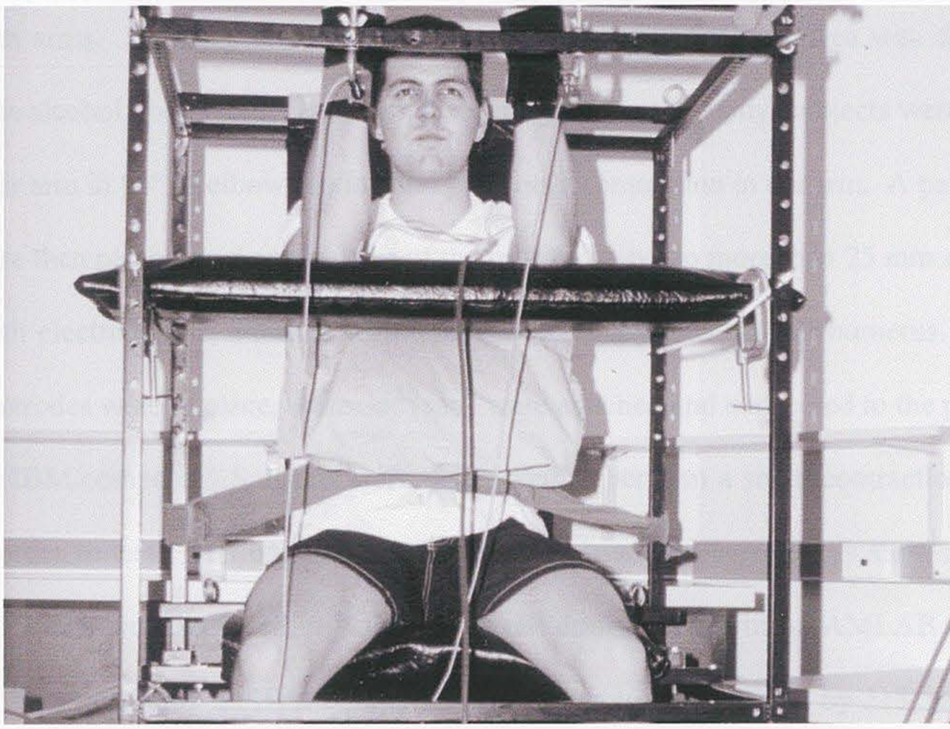


Figure 3.2. Front view of a subject restrained in the force chair prior to protocol.

3.2.1 Calibration Procedure

Prior to the arrival of each subject, both strain gauges were calibrated using fixed weight calibration plates. This procedure entailed placing a hook on the wrist strap of each individual strain gauge and cumulatively hanging a total of four fixed weight plates from the hook. Checks were made to ensure that the resulting force matched a preset line visually displayed in the AMLAB software, that was representative of the Newtons expected for each weight. Each fixed weight plate weighed 11.34 kg, which equated to 111.245 Newtons. To confirm linearity in strain gauge output, a regression line was established between Volts and Newtons and is displayed in Appendix F.

3.3 Recording and Analysis of Electromyography

Surface EMG electrodes were used to measure electrical activity in the biceps brachii of both arms. Before electrodes were attached, the relevant skin area was shaved, cleaned with alcohol, then dried. To assist in locating the muscle belly, subjects were asked to hold their arm in 90° of elbow flexion and perform a contraction in the arm. A pair of electrodes were then placed on the mid point of the muscle belly, no more than 25 mm apart, while the earth electrode was attached to the medial epicondyle of the left humerus. Once surface electrodes were in place, electrode leads were attached and connected to the preamplifier on the IBM computer. Subjects were then asked to perform a small contraction of both arms in order to test EMG output. An example of electrode placement is shown in Figure 3.2. EMG data were recorded in Volts and stored during testing using AMLAB data diagnostic software operating an IBM computer. EMG data were amplified by 218, sampled at 1000 Hz, and averaged (root mean squared – rms). Analysis of rmsEMG data involved the offline selection and averaging of half a second of rmsEMG data that were applicable to relevant contractions. Selection of data was achieved through the placement of cursors (available in AMLAB software), on either side of relevant data.

Figure 3.2. Photograph demonstrating the placement of electrodes on subject's arm.

3.4 Determination of Maximal Voluntary Contraction (MVC) and Recording of Force Data

In order to limit input from synergist muscles when determining MVC, subjects were restrained in a force chair with a velcro strap fastened around the waist, and a clamped padded board and pillow placed against their chest (refer to Figure 3.1). The padded board, used also for placing the arms on, was adjusted for each subject's height. Wrists were padded and strain gauge straps placed around them. Both arms were positioned on the padded board in 90° of elbow flexion, with wrists in the supine position. In order to achieve an MVC, subjects were informed that when given the cue, they were to pull the wrist of their reference arm as hard as possible toward their corresponding shoulder for approximately 3 – 4 seconds. When the cue was given, the investigator verbally encouraged the subject in performing the task. Three MVC's were performed with a two-minute rest interval between each contraction. Force data were recorded and stored using AMLAB diagnostic software operating an IBM computer. Force data relating to MVC and other relevant contractions, were selected offline and averaged through the employment of cursors contained in AMLAB software.

3.5 CR-10 Scale

Prior to testing, subjects were acquainted with the use of the CR-10 scale, and carefully instructed that RPE values reported during testing should reflect the effort sensed as a consequence of the task. RPE data was recorded in specific data collection sheets (Appendix G), while an illustration of the CR-10 scale can be found in Appendix H.

3.6 Pilot Study

Prior to formal testing a pilot study was employed in order to test the reliability of measurements, as well as to familiarise the investigator with equipment. Five subjects (who were not part of the main study) participated, with each subject tested on two separate occasions. The protocol, which was identical for both occasions and applied separately to both arms, consisted of each subject performing three MVC's followed by single contractions in the same arm that represented 80%, 60%, 40% and 20% of their highest MVC. To assist subjects in achieving target sub-maximal contractions, target force and actual reference arm force were displayed on a PC monitor. Contractions were performed in random order with a two-minute rest interval between each contraction.

3.7 Study Design

The testing procedure took approximately 65 minutes and consisted of the attainment of baseline measurements (10 minutes), the fatiguing task (45 minutes) and a recovery protocol (10 minutes). Prior to testing, completed questionnaires were reviewed, the procedure was demonstrated, and any questions or concerns addressed.

3.7.1 Baseline Measurements

In order to establish baseline values, all subjects commenced the session by performing three MVC's in their reference (non-dominant) arm. The greatest MVC for the reference arm was measured, and subjects were then asked to perform contractions in this arm equating to 70%, 50% and 30% of their largest MVC. Target force was displayed on a PC monitor along with reference arm force. Contractions were made in random order and lasted for approximately eight seconds. Approximately four seconds after the commencement of each sub-maximal contraction, subjects attempted to match the force of

the reference arm with the dominant arm. Both contractions were then held for a further four seconds with no visual cue being given for attempted matches made by the dominant arm. Associated RPE scores were recorded for each contraction made in the reference arm. The entire procedure was then repeated with MVC's and sub-maximal contractions performed in the dominant arm, along with attempted matches made this time by the reference arm. RPE values were not recorded for the contractions made during this part of the procedure. Force and rmsEMG values were recorded for all contractions.

3.7.2 Fatiguing Task

The fatiguing task consisted of intermittent sub-maximal contractions (7 s duration, 3 s rest intervals) of the reference (non-dominant) arm, at a force equivalent to 30% of MVC of the reference arm, for 45 minutes. Visual feedback to subjects consisted of the target force and reference arm force displayed on a PC monitor. The reference force output was monitored by the investigator throughout the procedure to ensure subject compliance. Each minute, subjects were instructed to match the force of the reference arm with their dominant arm (without the benefit of visual feedback for the dominant arm), except for every fifth minute when an MVC was performed in the reference arm. Recordings of force and rmsEMG activity were made every minute for 30 seconds, while RPE was recorded 30 seconds after each matching or MVC contraction.

3.7.3 Recovery Protocol

At the completion of the fatiguing task, subjects commenced a recovery protocol that involved them performing a 30% of MVC of the reference arm. Target force was visually displayed on a PC monitor along with reference arm force. After three seconds, subjects were asked to match the force of the reference arm by contraction of the dominant arm,

without the benefit of visual feedback for the matching arm. After the match was attempted, subjects were then encouraged to perform a MVC in the reference arm. This procedure occurred at 1, 3, 5 and 10 minutes after completion of the fatiguing task.

3.8 Data and Statistical Analysis

This study involved four protocols, with data and statistical analysis varying for each one. Values in the results section are presented as mean ± standard deviation unless otherwise stated. All relevant raw data pertaining to results can be found in Appendices I (pilot study) and J (formal testing). In order to avoid repetition, it is intended that this entire section be read in conjunction with chapter four.

3.8.1 Data Analysis of Pilot Study Results

Results of the pilot study were analysed using a Pearson product-moment correlation coefficient for MVC force and rmsEMG data in the right and left arms of all subjects. Method error (calculation demonstrated by Thorstensson, cited in MacDougall, Wenger & Green, 1991) and coefficients variation were calculated for force and rmsEMG data for MVC, as well as contractions made at 20, 40, 60, and 80% of MVC.

3.8.2 Data and Statistical Analysis of Baseline Measurements

Responses to the POMS questionnaire were scaled, averaged, and presented as standard T scores. According to McNair, Lorr and Droppleman (1992, p. 2) “the mean standard score for each scale is 50 with a standard deviation of 10”. MVC results were recorded in Newtons for force and Volts for rmsEMG, while all submaximal force and rmsEMG data were expressed as percentages of individual peak MVC values. RPE data were recorded according to numeric values pertaining to the CR-10 scale. Independent t tests were

applied to individual data so to test for statistically significant differences between groups. Means were also calculated for MVC force, MVC rmsEMG, matching force, matching rmsEMG, and RPE data, and compared between groups in order to identify trends.

3.8.3 Data and Statistical Analysis of Results Recorded During the Fatiguing Task

MVC values were recorded prior to and for every fifth minute during the fatiguing task. An ANOVA with repeated measures was performed on individual normalised MVC force and MVC rmsEMG values in order to test for any statistically significant difference between groups and between group by time. Means for each time interval were calculated and compared between groups in order to identify trends.

Apart from every fifth minute, matching force, matching rmsEMG and reference rmsEMG were recorded for every other minute during the 45 minute task. All individual data were expressed as a percentage of individual peak MVC values determined prior to the fatiguing task. Individual normalised data were then averaged for each four-minute interval preceding MVC production. An ANOVA with repeated measures was performed on this data in order to determine if any statistically significant difference occurred between groups and between group by time. In order to identify trends, means for each four-minute time intervals were calculated and compared between groups. A Pearson product-moment correlation coefficient was performed on means for matching force and reference rmsEMG in both CFS and control groups, in order to determine if an association existed between these two variables.

RPE data were averaged for the first and every fifth minute. An ANOVA with repeated measures was applied to this data to test for any statistically significant difference between

groups and between group by time. In order to identify trends, means for each time intervals were calculated and compared between groups.

3.8.4 Data and Statistical Analysis of Results Recorded During Recovery

MVC force, MVC rmsEMG, matching force, matching rmsEMG and reference rmsEMG were recorded at one, three, five and ten minutes post the fatiguing task. Independent t tests were performed on individual normalised values for each time interval in order to determine if any statistically significant difference occurred between groups. Means for each time interval were calculated and compared between groups in order to identify any trends.

3.9 Delimitations and Limitations

3.9.1 Subject Delimitations

Subject delimitations imposed by the investigator, related to attempts to match CFS subjects with control subjects, as well as selecting only CFS subjects who had been medically diagnosed with CFS as triggered by an infectious incident. Diagnosis also needed to be made within a 6 month to 3 year period. Candidates who were involved in any upper body strength training were also excluded from this study.

3.9.2 Subject Limitations

While every attempt was made to appropriately match the CFS group with the control group, limitations related to honest responses to the questionnaires, strength, endurance capabilities, motivational levels, tolerance of pain, fibre type and other psychological factors that would impact on subjective ratings of perceived exertion.

3.9.3 Research Limitations

This study was limited by time, with consequent constraints in the number of subjects who could be tested. Twitch interpolation, which allows for the objective assessment of MVC, was also not employed due to time constraints.

CHAPTER FOUR

RESULTS

4.1 Pilot Study Results

A Pearson product-moment correlation coefficient for MVC force in the right and left arms resulted in r = 0.98 (Rsq = 95%) and r = 0.97 (Rsq = 94%) respectively (Figure 4.1). Results for rmsEMG values equated to r = 0.94 (Rsq = 88%) in the right arm and r = 0.89 (Rsq = 80%) in the left arm (Figure 4.2). These values indicated a strong association between tests, suggesting that the testing procedures and equipment used in this pilot study produced reliable results in relation to MVC values. Method error for MVC in the right arm was 9.3 N for force and 0.018 V for rmsEMG, equating to coefficient variations of 3% and 8% respectively. MVC in the left arm resulted in a method error of 24.6 N for force and 0.028 V for rmsEMG and is represented by coefficient variations of 7% and 11%.

The relationship between force and rmsEMG in the right and left arms for both tests is presented in Figure 4.3. Method error and coefficient variations for contractions 80, 60, 40 and 20% of MVC were calculated and resulted in coefficient variations ranging from 3 – 10% for force, with rmsEMG values ranging from 15 – 25%. The larger method error associated with rmsEMG results most likely pertains to the highly specific and sensitive nature associated with the importance of electrode placement in determining the motor unit populations sampled on each occasion (De la Barrera & Milner, 1994).

Left Arm Test-Retest Correlation for Force | Right Arm Test-Retest Correlation for Force

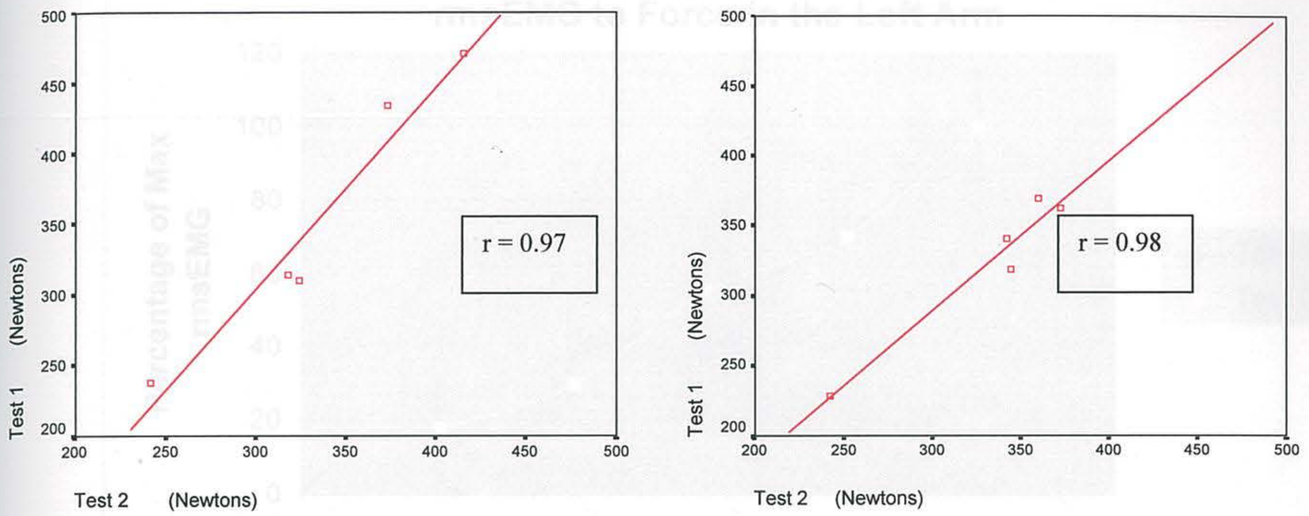


Figure 4.1 Test-retest correlation for maximum voluntary elbow flexion in the left and right arms (n = 5). Each result represents the peak force value obtained from three maximum efforts on separate occasions.

Left Arm Test-Retest Correlation (rmsEMG) | Right Arm Test-Retest Correlation (rmsEMG)

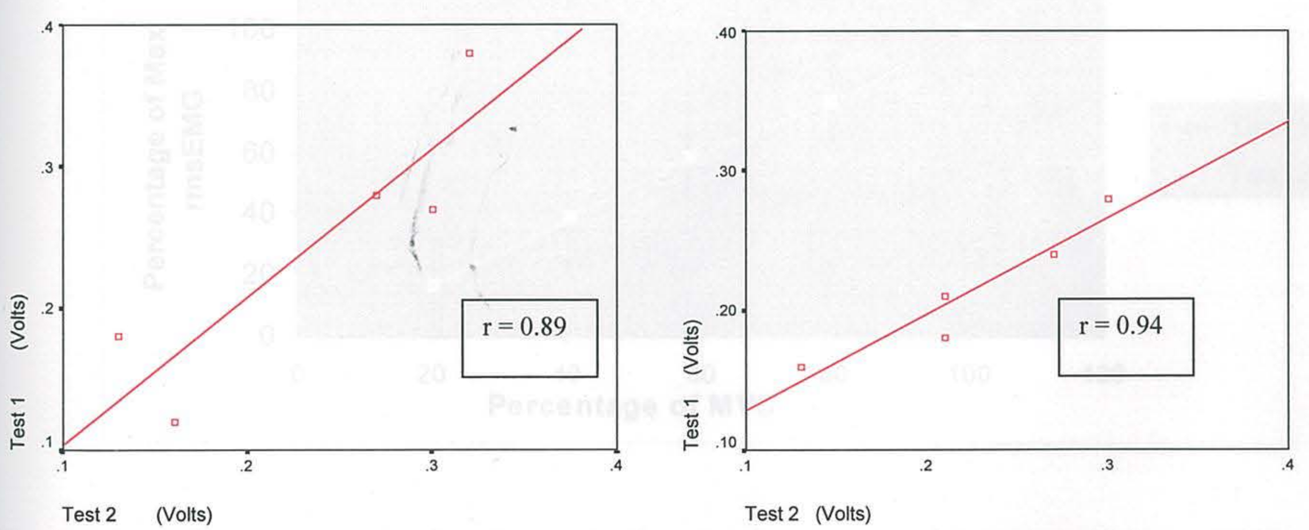
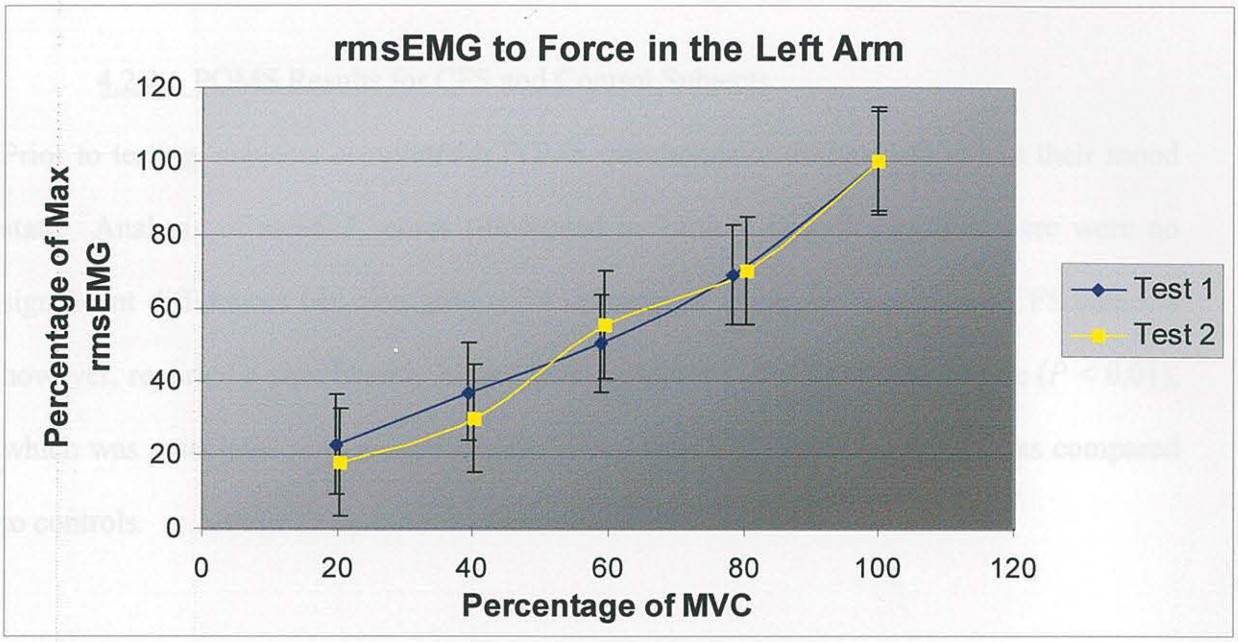


Figure 4.2. Test-retest correlation for maximum voluntary elbow flexion rmsEMG activity in the left and right arms (n = 5). Each result represents the average of 0.5 seconds of selected data sampled at 1000Hz.

Graph A



Graph B

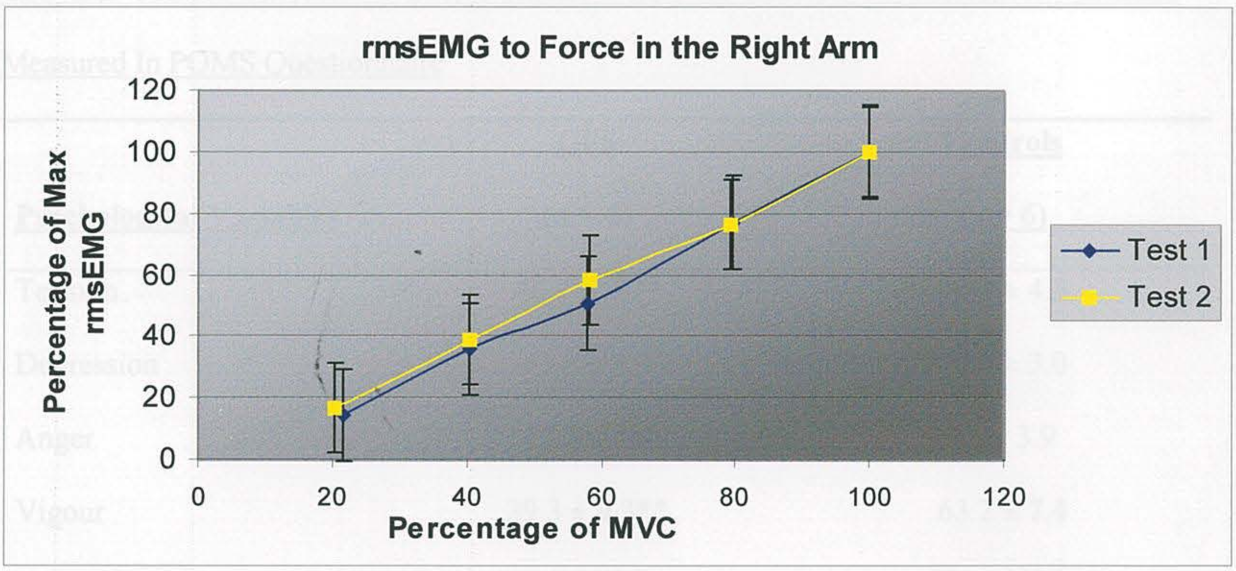


Figure 4.3 Test-retest results for pilot study (n = 5). Graph A represents normalised rmsEMG to normalised force for contractions representative of 20, 40, 60, 80% of MVC and MVC in the left arm. Graph B represents normalised rmsEMG to normalised force for contractions representative of 20, 40, 60, 80% of MVC and MVC in the right arm. Results are mean ± SEM for five subjects.

4.2 Results for Baseline Measurements Made Prior to Fatiguing Task

4.2.1 POMS Results for CFS and Control Subjects

Prior to testing, subjects completed a POMS questionnaire designed to assess their mood state. Analysis of mean T scores (illustrated in Table 4.1) indicated that there were no significant differences between groups for depression, anger, or confusion. CFS subjects however, reported a significantly higher level of tension ($P < 0.05$) and fatigue ($P < 0.01$), which was associated with a significantly lower degree of vigour ($P < 0.01$), as compared to controls.

Table 4.1

CFS and Control Subjects' T Scores (mean ± SD) for Specific Psychological Variables Measured In POMS Questionnaire

Psychological Variables	**CFS (n = 6)**	**Controls (n = 6)**
Tension	46.7 ± 9.7*	36.2 ± 4.3
Depression	43.8 ± 8.3	40.5 ± 3.0
Anger	47.2 ± 5.8	42 ± 3.9
Vigour	39.3 ± 9.3**	63.2 ± 7.4
Fatigue	64.5 ± 5.2**	38.5 ± 4.8
Confusion	50.5 ± 16.8	37.8 ± 4.0

* and ** denote significant differences between groups *($P < 0.05$), while ** ($P < 0.01$).

Independent t tests were two-tailed and included a 95% confidence interval.

4.2.2 MVC Force Results for CFS and Control Groups

While elbow flexor MVC strength was similar between groups, CFS subjects proved to be slightly stronger (Figure 4.4). This is demonstrated by mean values of 303.5 ± 121.7 N for the CFS group as compared to 288.0 ± 61.7 N for controls in the reference arm, with a slightly smaller difference in the matching arm (320.6 ± 127.7 N vs 313.5 ± 67.3 N). There were no significant differences between the reference and matching arms in either group.

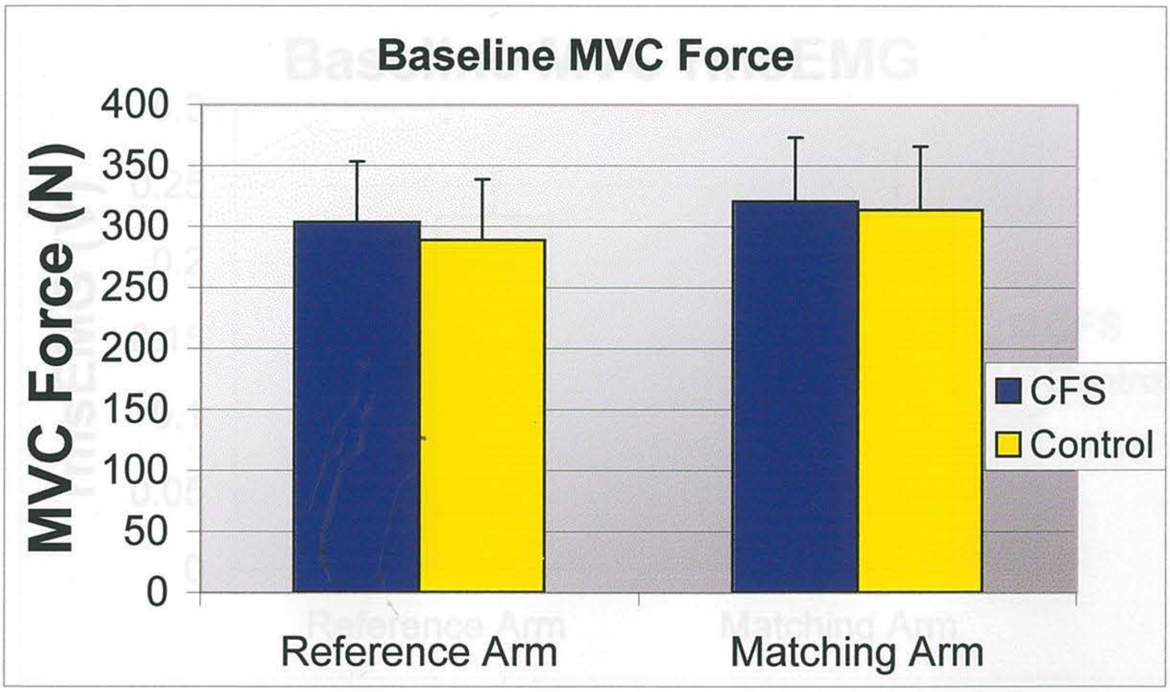


Figure 4.4. MVC force values (mean + SEM) for reference and matching arms in CFS (n = 6) and control (n = 6) groups.

4.2.3 MVC rmsEMG Results for CFS and Control Groups

While there was no significant differences between groups for MVC rmsEMG, comparison of mean values (illustrated in Figure 4.5) indicated higher amplitude in the reference arm for the control group (0.23 ± 0.09 V), as compared to the CFS group (0.18 ± 0.10 V). Results for the matching arm were also higher for the control group (0.23 ± 0.09 vs 0.18 ± 0.11 V).

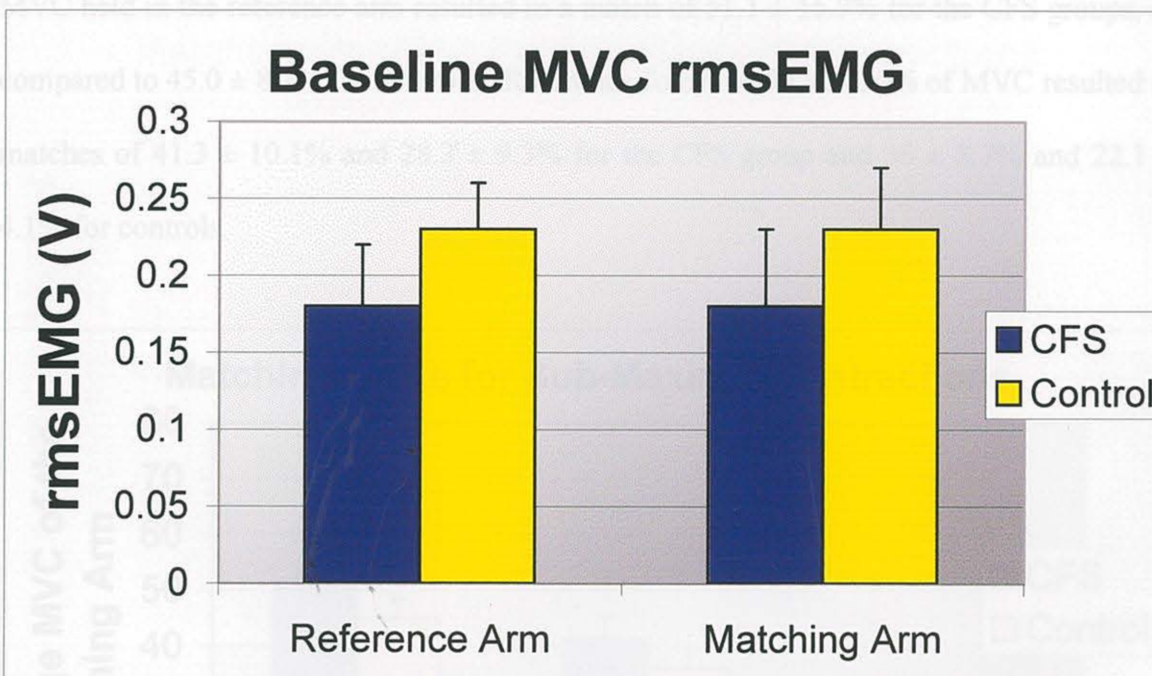


Figure 4.5. MVC rmsEMG values (mean + SEM) for reference and matching arms in CFS (n = 6) and control (n = 6) groups.

4.2.4 Matching Force Values for Sub-Maximal Contractions

Figure 4.6 illustrates the forces achieved when subjects attempted to match varying sub-maximal contractions of 30, 50 and 70% of MVC held in the reference arm. Comparison of means demonstrated that both groups underestimated the reference force, with the greatest difference occurring with attempts to match a 70% of MVC. The difficulty in matching a high level reference force is consistent with the findings of Jones and Hunter (1983a), who reported that as the magnitude of a reference force increased, the ability to match it decreased. Results, while not statistically significant, demonstrated that CFS subjects produced greater averaged matches when compared to controls. Attempts to match a 70% MVC held in the reference arm resulted in a match of 51.1 ± 16.9% for the CFS groups, as compared to 45.0 ± 8.7% for controls. Reference forces of 50 and 30% of MVC resulted in matches of 41.3 ± 10.1% and 28.3 ± 9.3% for the CFS group and 36 ± 8.7% and 22.1 ± 4.1% for controls.

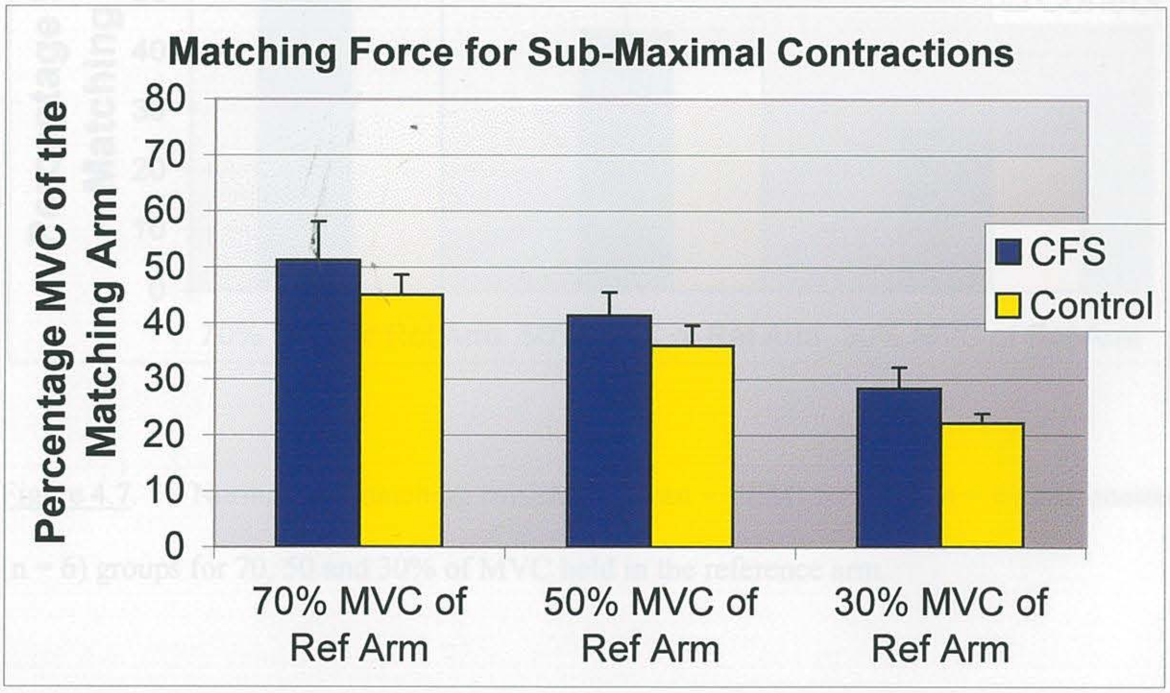


Figure 4.6. Normalised matching force (mean + SEM) for CFS (n = 6) and control (n = 6) groups for 70, 50, and 30% MVC held in the reference arm.

4.2.5 Matching rmsEMG Values for Sub Maximal Contractions

Matching rmsEMG for both groups followed a similar pattern to matching force (refer 4.2.4), in that matching rmsEMG means were below the reference target for each sub-maximal contraction (Figure 4.7). Results between groups were variable as demonstrated by the control group displaying higher matching rmsEMG when attempting to match a 70% MVC held in the reference arm, while the CFS group produced greater rmsEMG amplitude when attempting to match a 50% and 30% MVC reference force. There were no significant differences between groups in matching rmsEMG for sub-maximal contractions.

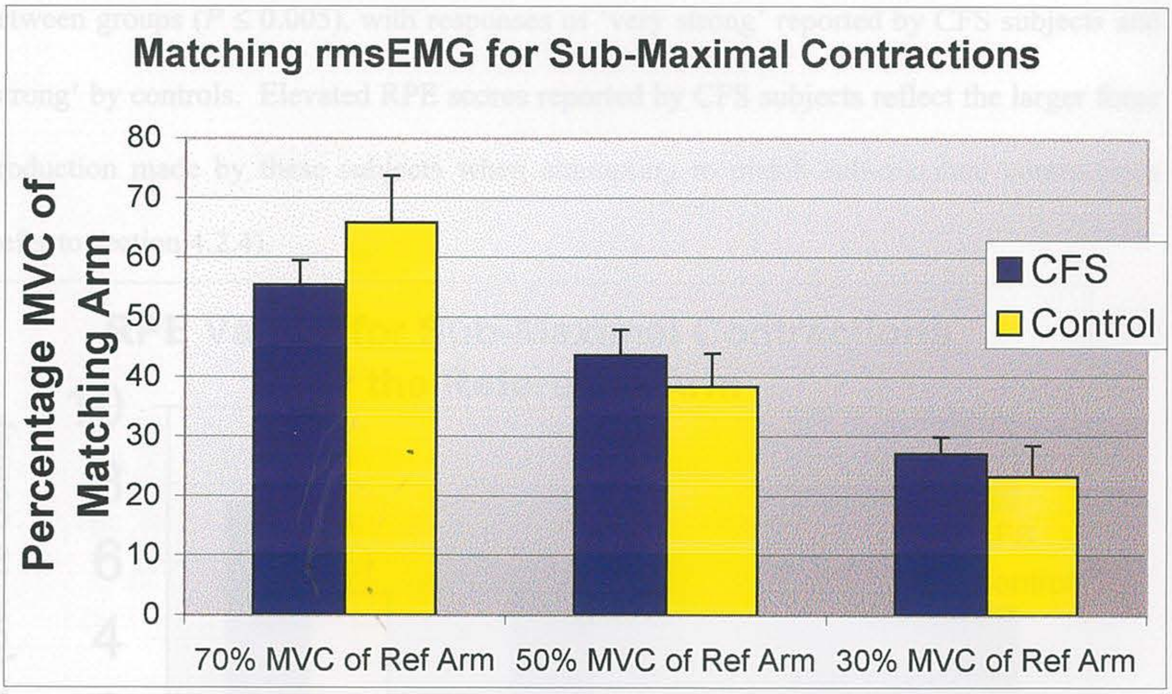


Figure 4.7. Normalised matching rmsEMG (mean + SEM) for CFS (n = 6) and control (n = 6) groups for 70, 50 and 30% of MVC held in the reference arm.

4.2.6 RPE Responses During Sub-Maximal Contractions

Comparison of mean RPE values for contractions performed at 70%, 50%, and 30% of individual MVC are illustrated in Figure 4.8. Significant differences between groups were observed, with the CFS group reporting higher RPE scores associated with all three sub-maximal contractions. The greatest difference between groups for RPE scores occurred for contractions made at 50% MVC ($P \leq 0.001$). This contraction elicited responses of 'somewhat strong' to 'very strong' from CFS subjects, while controls rated it as 'weak' to 'moderate'. Contractions performed at 70% of MVC elicited the least significant difference between groups ($P \leq 0.005$), with responses of 'very strong' reported by CFS subjects and 'strong' by controls. Elevated RPE scores reported by CFS subjects reflect the larger force production made by these subjects when attempting to match sub-maximal contractions (refer to section 4.2.4).

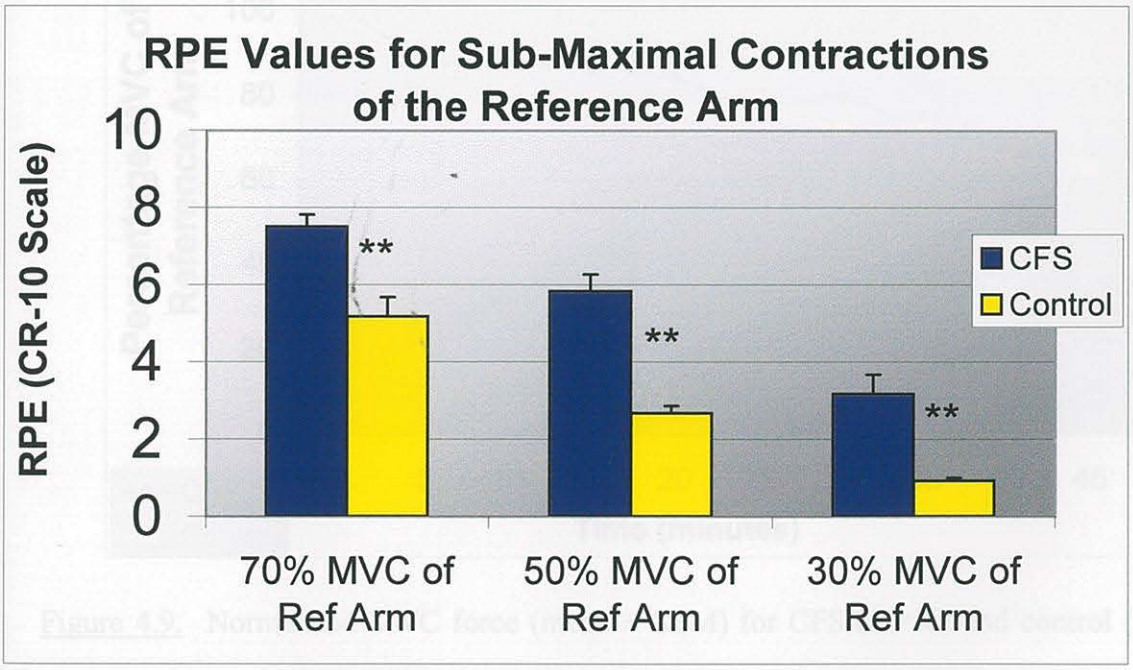


Figure 4.8. RPE values (mean + SEM) for 70, 50, and 30% of MVC performed in the reference arm for CFS group (n = 6) and control group (n = 6). ** Denotes significant difference between CFS and control groups ($P < 0.01$).

4.3. Fatiguing Task

4.3.1 MVC Force Results During the Fatiguing Task

Figure 4.9 illustrates a similar pattern in normalised mean MVC force for both groups over the 45 minute task. Both groups demonstrated a large decrement in force between the initial MVC and the five-minute mark (12% for CFS and 13% for controls), with force fluctuating between groups until the 35 minute mark. At this point MVC force was identical for both groups (72 ± 9%). The final ten minutes saw MVC force fall slightly more in the control group than in the CFS group, with final values for mean MVC force represented by 66 ± 18% and 62 ± 8% for the CFS and control groups respectively. An ANOVA with repeated measures demonstrated no significant difference in scores between groups.

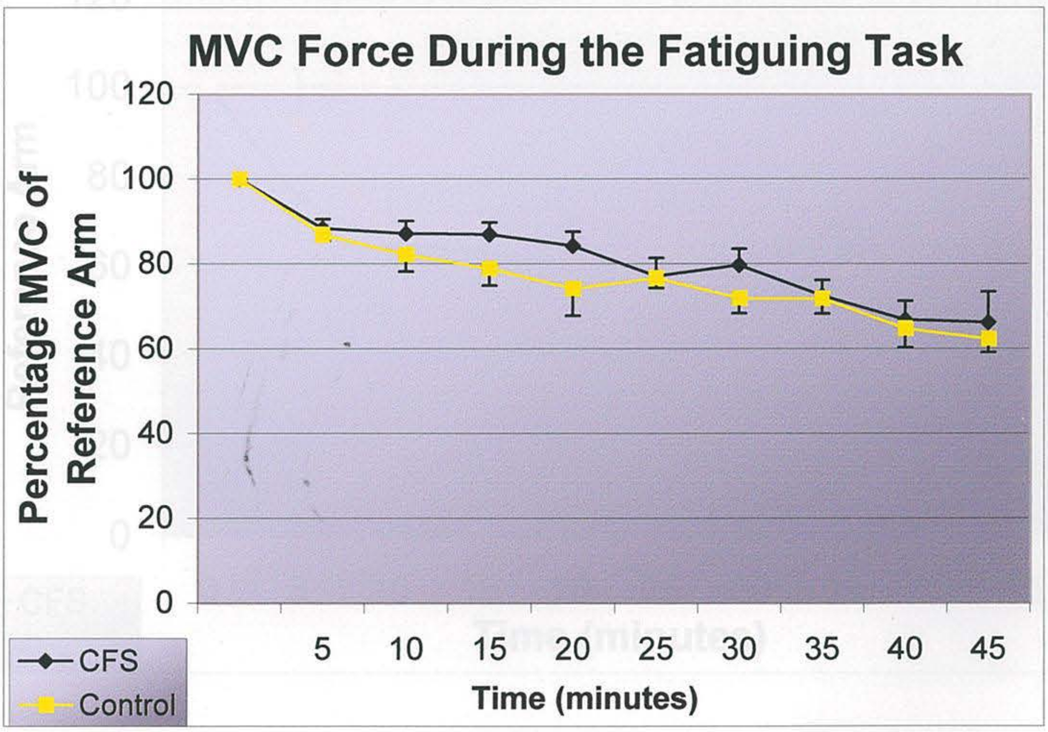


Figure 4.9. Normalised MVC force (mean ± SEM) for CFS (n = 6) and control (n = 6) groups recorded prior to and for every fifth minute during the fatiguing task. The first data point denotes the greatest MVC force achieved during baseline measurements and represents 100%.

4.3.2 MVC rmsEMG During the Fatiguing Task

MVC rmsEMG results demonstrated a similar pattern between the two groups for the 45 minute task (Figure 4.10). While a greater decline in MVC rmsEMG amplitude was evident in the CFS group between the initial recording and the five-minute mark (25% as opposed to 8%), both groups produced similar amplitude between the 10 and 35 minute mark. In the last ten minutes of the task, MVC rmsEMG amplitude rose slightly more in the control group than in the CFS group, resulting in a final difference of 8% between groups. Differences between groups were not significant.

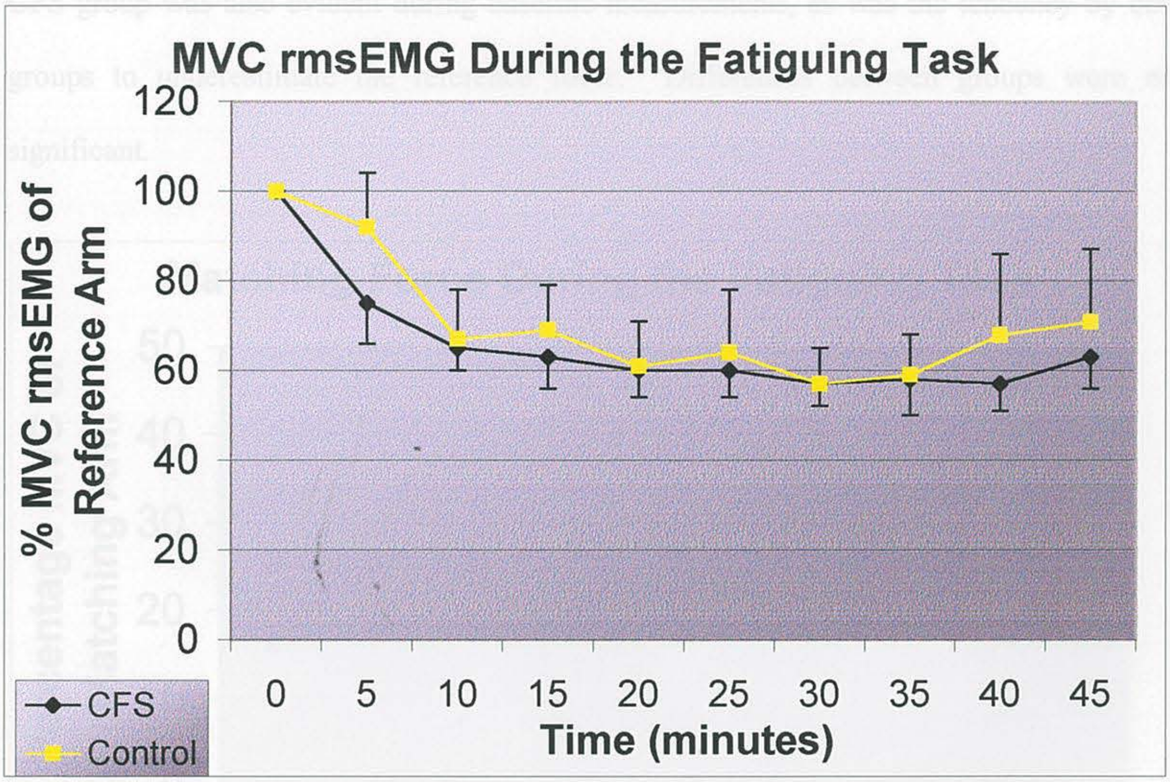


Figure 4.10. Normalised MVC rmsEMG (mean ± SEM) for CFS (n = 5) and control (n = 6) groups, recorded prior to and for every fifth minute during the fatiguing task. The first data point denotes MVC rmsEMG achieved during baseline measurements and represents 100%.

4.3.3 Matching Force During the Fatiguing Task

While normalised means for matching force were similar between groups (fluctuating between 4% and 7%), the CFS group produced a greater matching force for each respective time interval during the 45 minute task (Figure 4.11). Trends indicated that while both groups underestimated reference force for a large part of the task, matching force began to rise slightly for both groups at the 29 minute mark. The control group demonstrated a larger increase in matching force production between the 34 and 39 minute mark (3% vs 1%), while a dramatic increase in matching force production was evident for the CFS group in the final five minutes of the task (7% vs 4%). Larger matching force production by the CFS group was also evident during baseline measurements, as was the tendency by both groups to underestimate the reference force. Differences between groups were not significant.

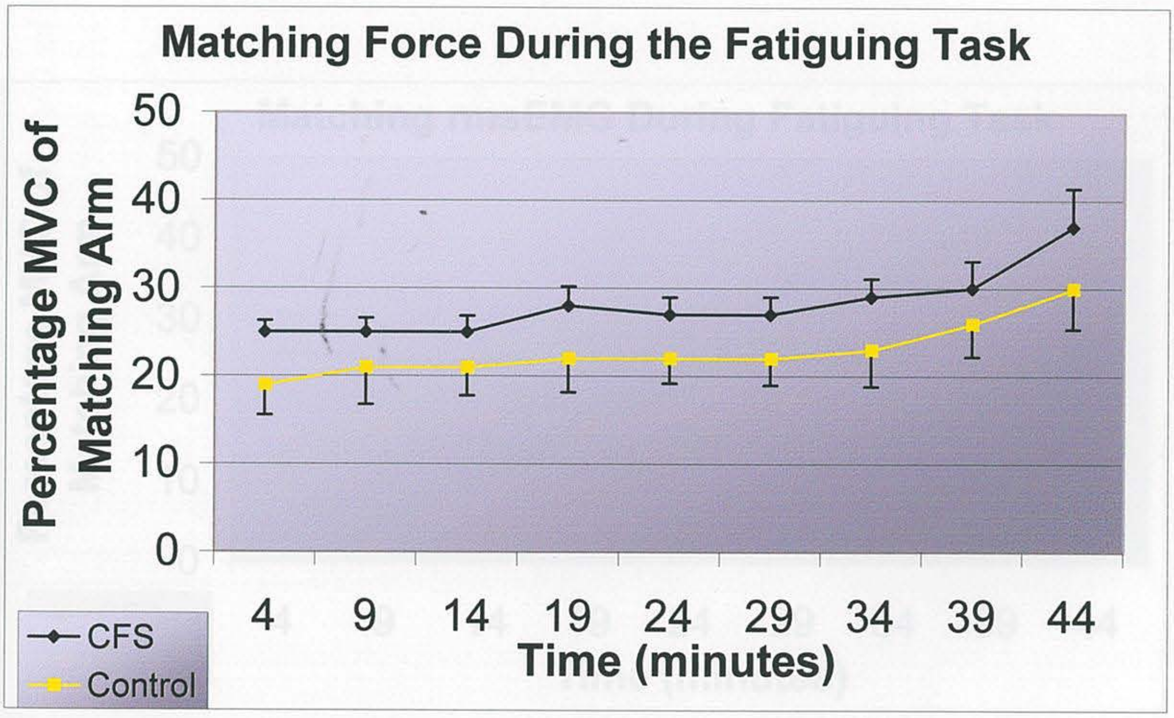


Figure 4.11. Normalised matching force values (mean ± SEM) for CFS (n = 6) and control (n = 6) groups, averaged for the four minute intervals prior to each MVC.

4.3.4 Matching rmsEMG During the Fatiguing Task

Trends for matching rmsEMG were similar between groups, with the CFS group demonstrating greater amplitude than controls for each respective time interval during the 45-minute task (Figure 4.12). This difference however, was reduced to only 5% by the end of the task. Trends were also similar to those produced for matching force. Matching rmsEMG amplitude began to rise for both groups toward the end of the task, increasing slightly earlier for the CFS group, as represented by a 2% increase between the 29 and 34 minute mark of the task. During the 34 and 39 minute mark, both groups experienced a similar increase in amplitude, with a larger increase being demonstrated by the control group for the last five minutes of the task (6% as compared to 2% for the CFS group). Higher matching rmsEMG amplitude was also demonstrated by the CFS group when attempting to match a similar contraction during baseline measurements. Differences between groups were not significant.

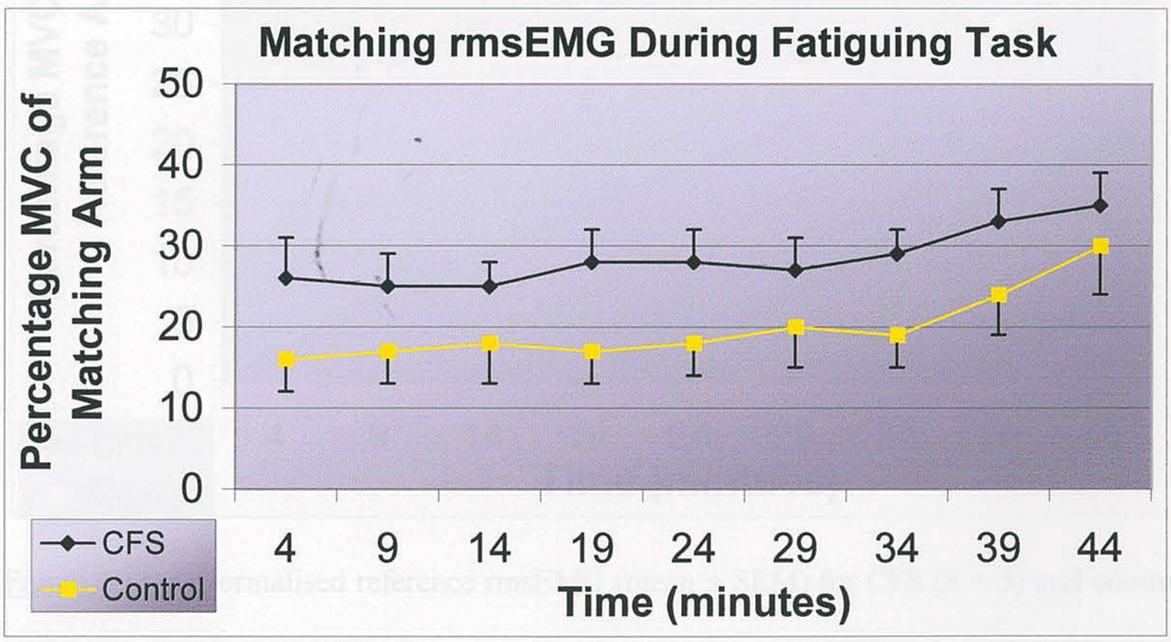


Figure 4.12. Normalised matching rmsEMG (mean ± SEM) for CFS (n = 6) and control (n = 6) groups, averaged for four minute intervals prior to each MVC.

4.3.5 Reference rmsEMG During the Fatiguing Task

Reference rmsEMG amplitude remained fairly constant between groups for the first 30 minute of the task. This was then followed by a gradual increase in amplitude, with both groups producing identical results at the 34 minute mark (28% respectively). At this point, amplitude in the CFS group increased at a faster rate as demonstrated by a 10% increase between 34 and 44 minutes, as compared to a 5% increase for controls for the same period. Once again, trends for reference rmsEMG were similar to those produced by matching force and matching rmsEMG, in that a greater increase in values was demonstrated towards the end of the task. Differences between groups were not significant.

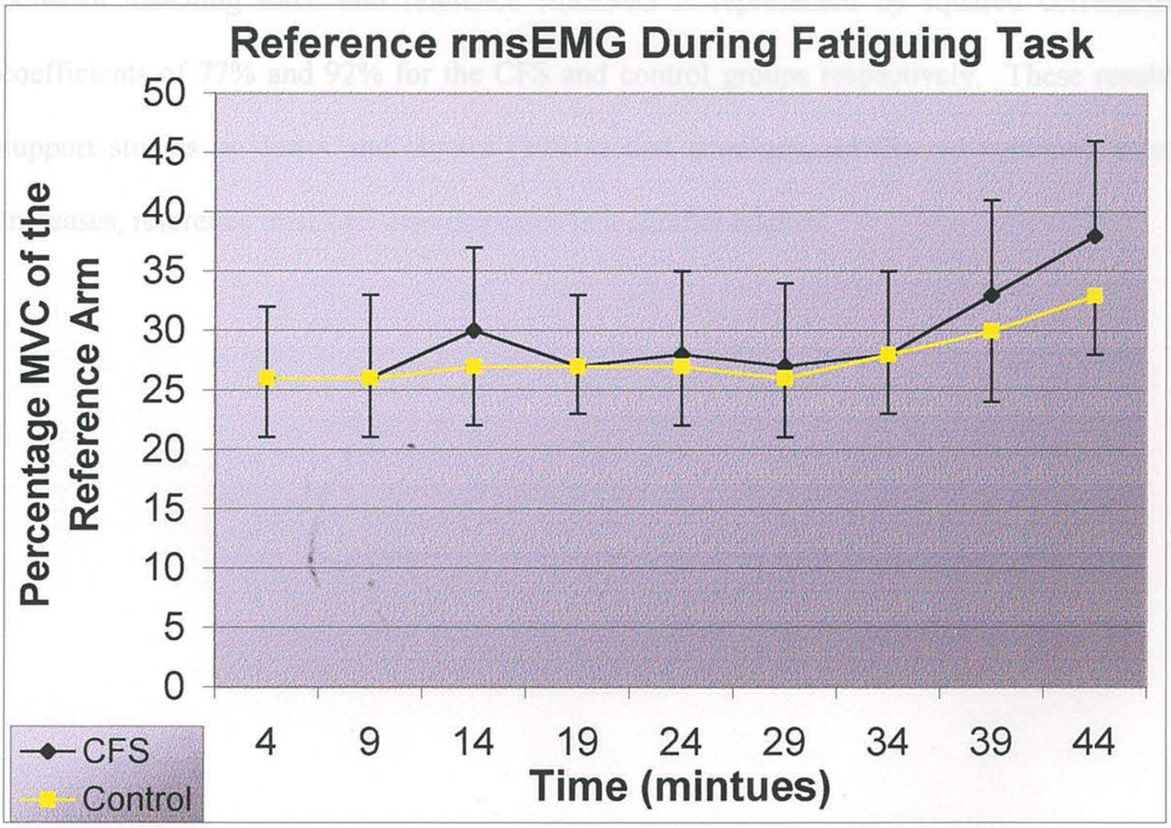
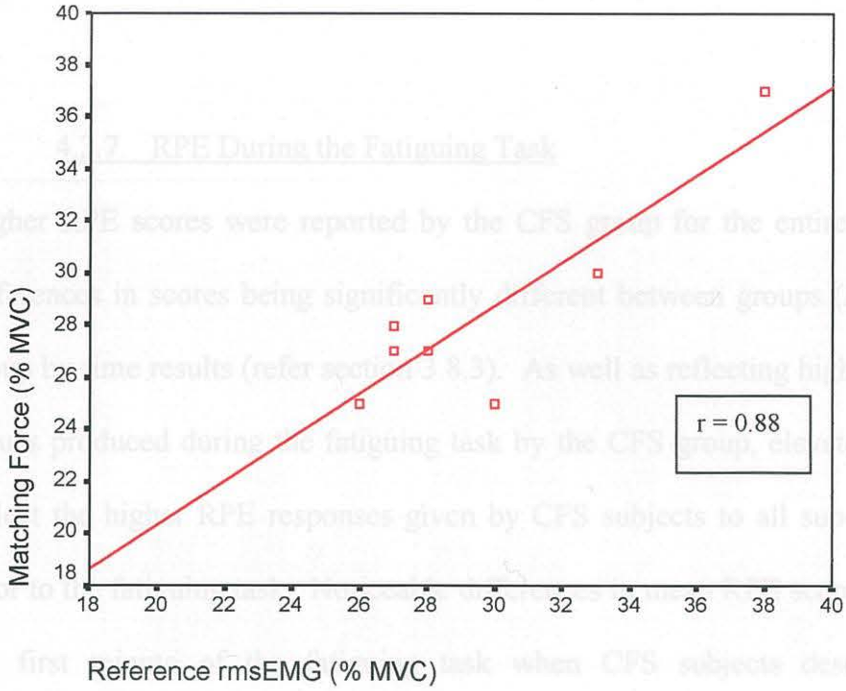


Figure 4.13. Normalised reference rmsEMG (mean ± SEM) for CFS (n = 5) and control (n = 6) groups, averaged for four minute intervals prior to each MVC.

4.3.6 Correlation Between Matching Force and Reference rmsEMG Results During the Fatiguing Task

The association between matching force in the dominant arm and rmsEMG amplitude in the reference arm is demonstrated by Pearson's correlation coefficients. A Pearson's correlation coefficient for normalised matching force and normalised reference rmsEMG, averaged for nine separate time intervals during the fatiguing task, resulted in $r = 0.88$ for the CFS group and $r = 0.96$ for the control group (Figure 4.14). A strong association between matching force and reference rmsEMG is represented by squared correlation coefficients of 77% and 92% for the CFS and control groups respectively. These results support studies by Jones and Hunter (1983a) that demonstrated that as matching force increases, reference rmsEMG also increases in a parallel manner.

Graph A CFS Group



Graph B Control Group

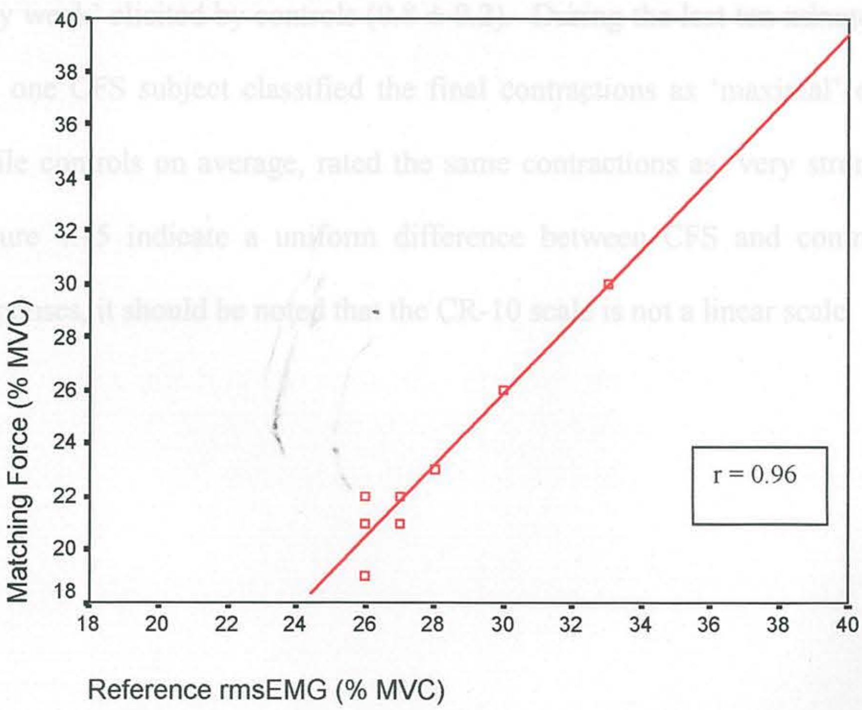


Figure 4.14. Correlation of normalised reference rmsEMG and normalised matching force, averaged over nine separate time intervals during the fatiguing task for the CFS group (n = 5) (Graph A), and for the control group (n = 6) (Graph B). (Only eight points shown as two represent the same values). Time intervals represent the 4th, 9th, 14th, 19th, 24th, 29th, 34th, 39th, and the 44th minute marks of the fatiguing task.

4.3.7 RPE During the Fatiguing Task

Higher RPE scores were reported by the CFS group for the entire 45 minute task, with differences in scores being significantly different between groups ($P < 0.05$), but not for group by time results (refer section 3.8.3). As well as reflecting higher force and rmsEMG values produced during the fatiguing task by the CFS group, elevated RPE values further reflect the higher RPE responses given by CFS subjects to all sub-maximal contractions prior to the fatiguing task. Noticeable differences in mean RPE scores were evident during the first minute of the fatiguing task when CFS subjects described the associated contractions as being 'weak' to 'moderate' (2.5 ± 1.2), as opposed to responses of 'very, very weak' elicited by controls (0.8 ± 0.2). During the last ten minutes of the protocol, all but one CFS subject classified the final contractions as 'maximal' or 'almost maximal', while controls on average, rated the same contractions as 'very strong'. While trends in Figure 4.15 indicate a uniform difference between CFS and control subjects for RPE responses, it should be noted that the CR-10 scale is not a linear scale.

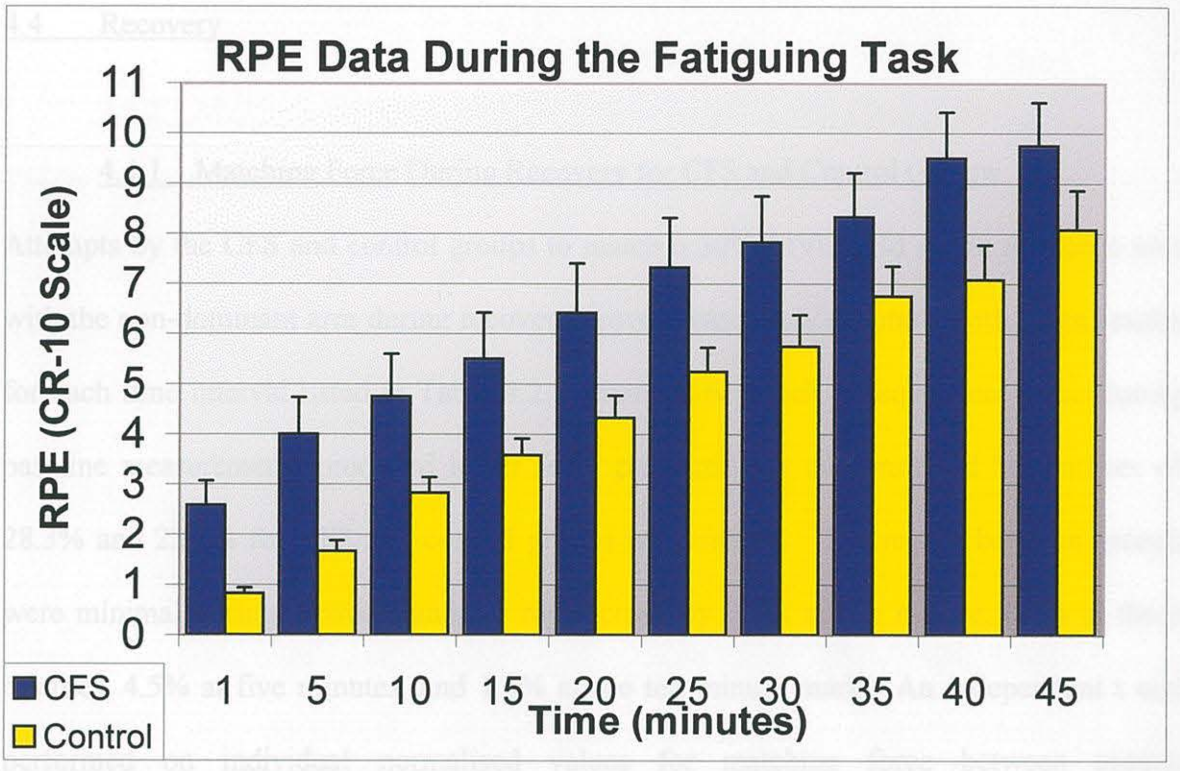


Figure 4.15. RPE data (mean ± SEM) for CFS (n = 6) and control (n = 6) groups for contractions performed in the reference arm during the first and every fifth minute of the fatiguing task. Significant differences ($P < 0.05$) were reported between groups but not for groups by time.

4.4 Recovery

4.4.1 Matching Force During Recovery for CFS and Control Groups

Attempts by the CFS and control groups to match a 30% MVC held in the reference arm with the non-dominant arm during recovery proved reasonably accurate, with mean results for each time interval listed in Table 4.2. Attempts to match an equivalent force during baseline measurements produced lower force production as demonstrated by matches of 28.3% and 22.1% for CFS and control groups respectively. Differences between groups were minimal during recovery and are represented by 0.1% at one minute, 0.6% at three minutes, 4.5% at five minutes, and 1.6% at the ten minute mark. An independent t test performed on individual normalised values for matching force between groups demonstrated no significant difference between groups.

Table 4.2

Mean Results For Normalised Matching Force for the CFS and Control Groups Recorded at 1, 3, 5, and 10 Minutes during the Recovery Protocol.

Recovery Time	**CFS group** (n = 6)	**Control group** (n = 6)
1 minute	32.1 ± 8.8%	32.3 ± 11.1%
3 minutes	33.1 ± 10.7%	33.8 ± 13%
5 minutes	35.2 ± 6.4%	30.6 ± 11.3%
10 minutes	31.3 ± 6%	29.6 ± 10.6%

4.4.2 Matching rmsEMG During Recovery for CFS and Control Groups

Results for averaged normalised matching rmsEMG are presented in Table 4.3. As well as indicating higher rmsEMG amplitude in the CFS group for the entire protocol, it was notable that the CFS group experienced a greater decline in rmsEMG amplitude over time (6.4%) than the control group (1.6%). An independent t test performed on individual normalised values revealed no significant differences between groups.

Table 4.3 Mean Results For Normalised Matching rmsEMG for the CFS and Control Groups Recorded at 1, 3, 5, and 10 Minutes during Recovery Protocol.

Recovery Time	**CFS group** (n = 5)	**Control group** (n = 5)
1 minute	35.6 ± 11.3%	26.4 ± 16%
3 minutes	30.8 ± 11.3%	22.0 ± 13.2%
5 minutes	29.2 ± 12.6%	23.8 ± 18.6%
10 minutes	29.2 ± 9.7%	24.8 ± 21.5%

4.4.3 Reference rmsEMG During Recovery for CFS and Control Groups

Results for averaged normalised reference rmsEMG are presented in Table 4.4. Reference rmsEMG was slightly higher in the CFS group when compared to the control group. Differences were 6.0% at one minute, 7.2% at three minutes, 5.8% at five minutes, and 2.9% at ten minutes. There were no significant differences between groups for reference rmsEMG amplitude.

Table 4.4

Mean Results For Normalised Reference rmsEMG for the CFS and Control Groups Recorded at 1, 3, 5, and 10 Minutes during Recovery Protocol.

Recovery Time	**CFS group** (n = 5)	**Control group** (n = 6)
1 minute	35 ± 21.4%	29.0 ± 10.4%
3 minutes	35.4 ± 24.4%	28.1 ± 10.3%
5 minutes	36.0 ± 24.2%	30.1 ± 13.7%
10 minutes	34.6 ± 24.9%	31.6 ± 14.4%

4.4.4 MVC Force Data for CFS and Control Groups During the Recovery Protocol

Comparison of normalised MVC force data between groups indicated that the CFS group showed a faster recovery of MVC force (Figure 4.16). One minute into recovery, results were similar (72.8 ± 7.3% vs 73.0 ± 7.1% for CFS and control groups respectively), while at the three minute mark, MVC force production for the CFS group had increased by 8.5%, as compared to a slight increase of 1.2% for controls. By five minutes, MVC force production for the CFS group had increased a further 11.3%, while controls only experienced a 6% rise. During the last five minutes, only a slight increase of 0.8% was observed in the CFS group, as compared to a larger increase for controls of 4%. Final MVC values were 94.6 ± 11.9% for the CFS group and 84.0 ± 7.9% for controls. Differences between groups were not significant.

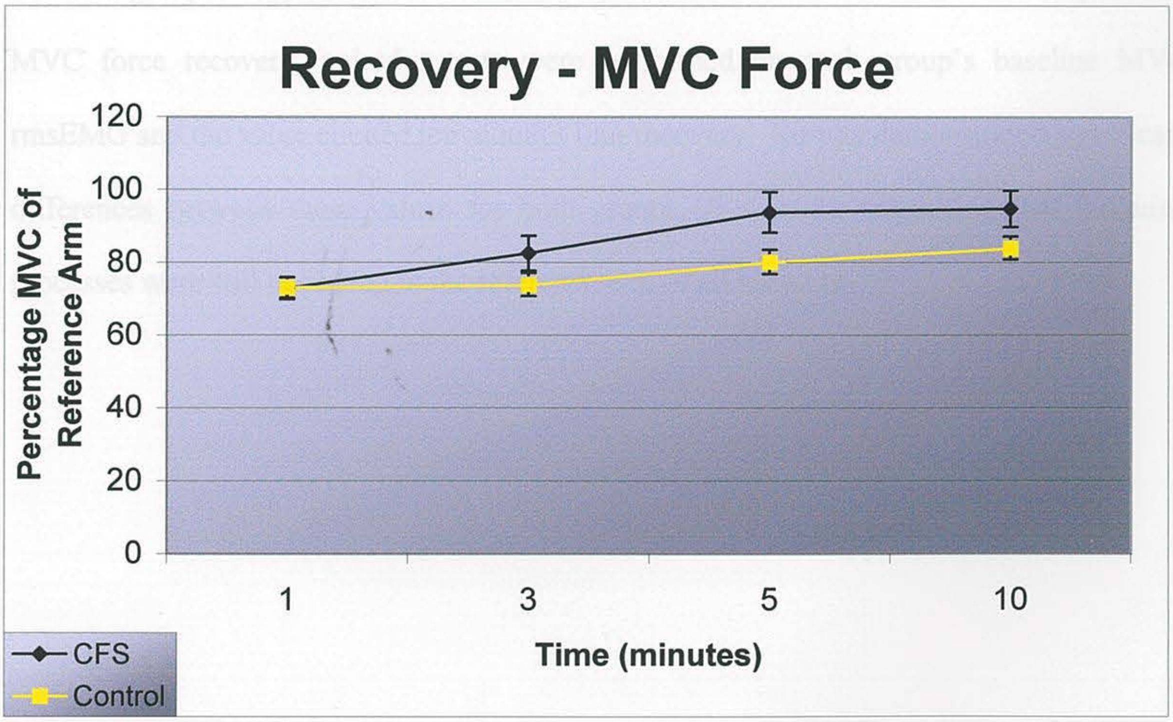


Figure 4.16. Normalised MVC force (means ± SEM) for the CFS group (n = 6) and the control group (n = 6) recorded at 1, 3, 5 and 10 minutes during the recovery protocol.

4.4.5 MVC rmsEMG for CFS and Control Groups During the Recovery Protocol

Normalised MVC rmsEMG data produced a pattern very similar to MVC force during recovery, with the major difference being that the control group demonstrated faster recovery (Figure 4.17). Results between groups were nearly identical at the one and three minute mark, as represented by differences of 0.2% and 0.9% respectively. At the three minute mark, MVC rmsEMG in the control group began to recover at a faster rate as demonstrated by an increase of 16% and 5.4% between three and five minutes for the control and CFS groups respectively. From this point, amplitude recovered slowly in both groups reaching 79.1 ± 18.1% for controls and 69.8 ± 11% for the CFS group ten minutes post the fatiguing task. Independent t tests indicated no significant differences in results between groups. Due to the slower recovery evident in MVC rmsEMG as compared to MVC force recovery, paired t tests were performed on each group's baseline MVC rmsEMG and the value elicited ten minutes into recovery. Results demonstrated significant differences between these values for both groups ($P < 0.05$), suggesting that fatiguing processes were still occurring in the reference arm of all subjects.

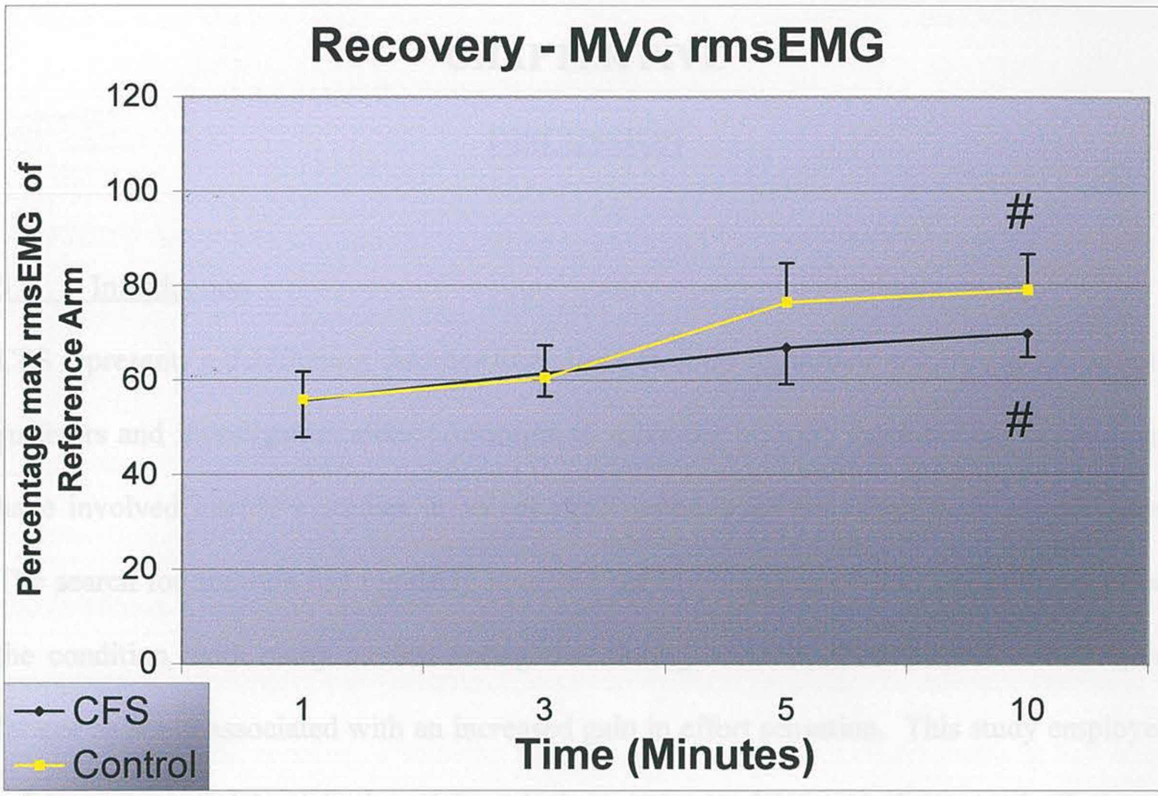


Figure 4.17. Normalised MVC rmsEMG (means ± SEM) for the CFS group (n = 5) and the control group (n = 6) recorded at 1, 3, 5 and 10 minutes during the recovery protocol. # denotes significant difference ($P < 0.05$) demonstrated by paired t tests between each group's baseline MVC rmsEMG and MVC rmsEMG elicited ten minutes post recovery.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

CFS represents a debilitating disorder that elicits feelings of despair and frustration in both sufferers and investigators alike. Attempts to solve the mystery surrounding its aetiology have involved intensive studies in recent years without the benefit of conclusive results. The search for answers has regularly involved the investigation of the fatigue that typifies the condition, with many studies noting that during exercise, CFS subjects often report fatigue as being associated with an increased gain in effort sensation. This study employed a fatiguing contralateral limb-matching task in order to determine if sense of effort was altered in CFS subjects as compared to control subjects. Evidence of an abnormal sense of effort in CFS subjects may imply an association between central mediators for effort sensation and the fatigue that characterises CFS. Assessing the extent of central fatigue during a fatiguing task is pertinent, in that central fatigue may promote sense of effort via impaired neural drive. In order to assess the development of central fatigue in CFS subjects, all subjects were requested to perform regular MVC's over the course of a fatiguing task. Four hypotheses were formulated in anticipation of outcomes for these tasks, with each one addressed separately in this discussion. Finally, the conclusion presents an overview of findings, as well as offers suggestions for further research related to the area of investigation in this study.

5.2 Central Fatigue and Sense of Effort

The first hypothesis postulated that CFS subjects would show a greater decline in maximal force during the fatiguing task when compared to control subjects. Results for normalised

intermittent MVC produced during the fatiguing task indicated no significant difference between groups, resulting in the rejection of this hypothesis.

Evaluating the ability to perform an MVC over the course of a fatiguing task may assist in determining the existence and development of central fatigue. According to Kent-Braun et al. (1993, p. 130), absence of a peripheral basis for fatigue, combined with the inability to fully activate skeletal muscle during maximal exercise "suggests a major role of central factors in the fatigue in CFS". Central fatigue, which is defined by an impaired motoneurone drive (Stokes et al. 1988), may contribute to a greater sense of effort by promoting a disproportionate mismatch between afferent and efferent signals, resulting in recalibration of the corollary discharge. This recalibration process is pertinent in that sense of effort is postulated to result from attention to the amplitude of the corollary discharge. While CFS and control subjects may be able to produce similar MVC's when the exercising muscle is fresh (unfatigued), this ability is tested in CFS subjects, as fatigue develops, by the possible emergence of certain psychological factors that can promote central fatigue. Psychological factors, exemplified by boredom and intolerance to pain, may lead to loss of motivation (Wessely & Edwards, 1993), as well as induce increased inhibition or reduced facilitation (Miller et al. 1996). As a psychological aetiology is often proposed for CFS (Wessely & Edwards, 1993), these factors may be more prevalent in CFS subjects than in controls, consequently resulting in larger decrements in MVC force by CFS subjects. Interestingly, not only was there no significant difference in results between groups in MVC force and MVC rmsEMG, comparison of normalised means demonstrated that the decline in MVC force was greater in the control group (38%) than in the CFS group (34%). Furthermore, results for MVC force between groups during recovery, while not statistically

significant, demonstrated a faster recovery in maximal force for the CFS group (94% of initial MVC) as compared to controls (84% of initial MVC).

Absence of an objective measure for maximal voluntary contractions, such as twitch interpolation, makes it difficult to confirm inferences. However, the similar MVC fatigability and recovery demonstrated between CFS and control subjects in this study, suggests that excessive central fatigue did not occur in CFS subjects. These results support research by Lloyd et al. (1988, 1991) and Wessely and Edwards (1993), that documented normal MVC capabilities in CFS subjects in the fresh and unfatigued states. Similar muscle function demonstrated between CFS and control subjects, further suggests that metabolic changes in the exercising muscle were not occurring excessively or prematurely in CFS subjects.

5.3 Matching Force Production During the Fatiguing Task.

The second hypothesis in this study stated that CFS subjects would exhibit increased force production in the matching limb during the fatiguing task, when compared to control subjects. Statistical analysis of results demonstrated no significant difference in matching force production between groups, resulting in the rejection of this hypothesis. While the results did not demonstrate statistical significance, comparison of normalised means confirmed that the CFS group produced consistently larger matches for each respective time interval, when compared to controls. Differences in matching force between groups increased from 4% to 7% during the last five minutes of the task. This trend implies that a more pronounced difference in matching force between groups may have resulted if the fatiguing task had continued for a longer duration. Increased matching force during a fatiguing contralateral limb matching task exemplifies attention to mediators for sense of

effort rather than the reference force (Cafarelli, 1988; Jones, 1995; McCloskey, 1978). Factors that may contribute to an increased sense of effort in CFS are discussed in section 5.5.

Attempts to accurately match the reference force of 30% proved unsuccessful during the early stages of the fatiguing task for both groups. It was only at the 40th minute mark that the CFS group successfully matched the reference force of 30%, while the control group did not match the reference force until the 45th minute. These results differ to studies reported by McCloskey et al. (1983), and Jones and Hunter (1983a) who demonstrated that subjects could accurately match the reference force during the early stages of the exercise when muscles were fresh (unfatigued). The discrepancy between findings in this study and those reported above, may relate to variations in subjects, equipment and protocol, as well as subject's familiarity with the protocol.

5.4 Reference rmsEMG Amplitude During the Fatiguing Task

The third hypothesis in this study postulated that CFS subjects would demonstrate greater reference rmsEMG amplitude during the fatiguing task, when compared to control subjects. Statistical analysis of results indicated no significant difference between groups for reference rmsEMG amplitude, resulting in the rejection of this hypothesis.

EMG amplitude represents an indirect measure of the final efferent input into a muscle and has been documented to increase steadily with fatigue in order to compensate for the loss of tension that occurs in fatigued motor units (Beliveau et al. 1992). In relation to contralateral limb matching tasks, Jones and Hunter (1983b) note that EMG amplitude of the reference limb parallels the change in perceived force, as measured by a matching

contraction in the unfatigued limb. This study supports theses findings as reference rmsEMG and force in the matching limb were found to be highly correlated during the fatiguing task for both the CFS group ($r = 0.88$) and the control group ($r = 0.96$) respectively. As the second hypothesis postulated that CFS subjects would produce a greater match during a fatiguing task when compared to control subjects, it was implied that matching and reference rmsEMG amplitude would also be higher in CFS subjects as a result of an associated greater sense of effort. The inability to substantiate a greater sense of effort in CFS subjects in statistical terms (refer to section 5.3), would support the rejection of this third hypothesis.

Comparison of normalised means between groups for reference rmsEMG confirmed higher amplitude in the CFS group during the last ten minutes of the task, which resulted in a 5% difference between groups. This enhanced neural drive, although not statistically significant, implies that a more fatiguing protocol may have resulted in a significantly higher reference rmsEMG in CFS subjects relative to controls. Support for this trend is provided by the elevated RPE scores reported toward the end of the fatiguing protocol by CFS subjects, that equated the effort as being between 'almost maximal' and 'maximal', subjectively demonstrating the escalating magnitude of the effort associated with the task for this group. While there was no significant difference in reference rmsEMG between groups during recovery, results were slightly higher in the CFS group, most likely reflecting an extension of the increased amplitude recorded by this group at the conclusion of the fatiguing task.

5.5 Sense of Effort During the Fatiguing Task.

The final hypothesis in this study stated that CFS subjects would report higher levels of perceived exertion from a CR–10 scale during the fatiguing task, when compared to controls. Analysis of individual RPE scores during the fatiguing task indicated that CFS subjects reported significantly higher RPE scores than control subjects. These results consequently support this last hypothesis.

Elevated RPE scores have been reported by CFS subjects during exercise in many studies (Gibson et al. 1993; Riley et al. 1990: Rowbottom, Keast, Pervan & Morton, 1998; Sisto et al. 1996), suggesting that CFS subjects associate similar levels of exercise with a greater sense of effort than controls. An important consideration relates to whether the higher RPE scores reported by CFS subjects during exercise reflect a greater sense of effort associated with the exercise or augmented pre-exercise values. Existence of a greater sense of effort in CFS subjects prior to exercise has been postulated in studies by Edwards et al. (1991), as a result of elevated RPE scores reported by CFS subjects at the commencement of exercise. Further studies by Gibson et al. (1993, p. 997), noted that the higher RPE scores reported by CFS subjects during an incremental cycle exercise, most likely reflected "CFS patients 'adding on' the subjective fatigue felt at rest to their effort scores during exercise". While this conclusion was speculative in that no pre-exercise RPE scores were recorded, results from this study support this conjecture. Baseline RPE scores reported in this study were significantly higher in CFS subjects when compared to control subjects ($P \leq 0.005$), suggesting that scores given during the fatiguing exercise represented an extension of these initial values. According to Gibson et al. (1993), elevated RPE scores reported by CFS subjects at the commencement of exercise would preclude the involvement of metabolic or electrophysiological factors that are associated with peripheral fatigue.

An abnormal sense of effort experienced prior to exercise was also reflected by responses given to a POMS questionnaire recorded prior to testing. Results demonstrated CFS subjects reporting significantly higher levels of subjective fatigue ($P \leq 0.0001$) associated with lower levels of vigour ($P = 0.001$), when compared to controls.

Wessely and Edwards (1993) suggest that the abnormal sense of effort reported by CFS patients in their studies may reflect a disproportionate mismatch between afferent feedback and efferent feedforward signals. In chapter two, it was postulated that a mismatch between afferent and efferent feedforward (corollary discharges) signals could result in the recalibration of the corollary discharge, with sense of effort determined by the resulting amplitude of this signal. Therefore a larger than normal (disproportionate) mismatch between afferent and efferent signals should result in greater amplitude of the corollary discharge and a simultaneous 'gain' in effort sense. A disproportionate mismatch between neural signals, as a result of augmented or attenuated afferent or efferent signals, may occur for a number of reasons, with overlap between physiological and psychological factors often evident.

Central fatigue and sense of effort are intrinsically linked in that mediators for central fatigue are reflected by a reduced motoneurone drive, with a concomitant influence on effort sense. Central fatigue can be induced or augmented by the triggering or amplification of relevant psychological symptoms such as apprehension or anxiety, which according to Miller et al. (1996), can result in the habitual inhibition of motor unit recruitment. Triggering or amplification of psychological mediators for central fatigue can be a consequence of the heightened sensitivity to physiological function that may occur when CFS patients vigilantly monitor these sensations in an attempt to control and reduce

symptoms (Wessely & Edwards, 1993). The likelihood of excessive mediators for central fatigue occurring in CFS subjects in this study (and therefore contributing to a disproportionate mismatch between neural signals in these subjects) are unlikely due to the similar muscle function demonstrated during the fatiguing task between the CFS and control groups.

As well as contributing to central fatigue, heightened attention to physiological mediators, such as one's heartbeat or ventilation, can amplify the existence of these functions, thereby augmenting afferent feedback (Wessely & Edwards, 1993). Heightened sensitivity can further intensify the sensation of pain often reported in CFS, possibly triggering psychological and motor inhibitory responses aimed at its avoidance (McClusky, 1993). As excessive occurrence of mediators for central fatigue was not established in CFS subjects during this study relative to controls, it is possible that a heightened sensitivity to sensory feedback took place in CFS subjects, consequently elevating their sense of effort.

A disproportionate mismatch between neural signals may be a consequence of loss of automatic functioning (Lawrie et al. 1997). Lawrie et al. have suggested that under normal circumstances, common activities evoke a preconceived motor command that is analogous to automatic functioning, with calibration between afferent and efferent signals usually being unnecessary or minimal. Lawrie et al. (1997) continue to suggest that automatic functioning may be impaired in CFS patients due to transient disturbances in the higher executive functions of the CNS as a result of disease. This situation is further compounded by lack of appropriate practice of skilled activity, resulting in the need for CFS patients to devote more attention to both motor and somatosensory feedback during activity (Edwards, 1992). Slow and deliberate movement, which deprives patients of the learned automaticity

of the motor skill, exemplifies this process (Edwards, 1992). The switch from automatic functioning to attention focusing may promote heightened sensitivity, resulting in a gain in afferent inflow and a consequent increase in effort sense. The need for greater attention to movement, as well as to cognitive tasks, was described by all CFS subjects in this study.

Loss of automatic functioning may occur as a result of deconditioning. Deconditioning often occurs in CFS in response to long periods of inactivity taken by these patients in an effort to reduce symptoms. As well as increasing the likelihood and severity of the delayed onset of muscle soreness when normal activity is resumed, deconditioning can alter the subjective difficulty of a task (Jain & DeLisa, 1998). Activity that once was aerobic becomes anaerobic through deconditioning, with consequent decreases in plasma and muscle pH being monitored by the sensory cortex via increased afferent feedback, resulting in a gain in effort sense. Deconditioning can also promote psychological responses such as apprehension and anxiety regarding activity, with a possible motor inhibitory response reducing neural drive (Wessely & Edwards, 1993). While all CFS subjects in this study reported long periods of inactivity associated with their disorder, the degree of deconditioning (and consequent afferent feedback), is dependent on the time duration of this inactivity, activity levels prior to the onset of CFS, as well as subsequent exercise. The level of deconditioning, if in existence, will therefore be varied in each subject. Assessment of aerobic capacity prior to testing may lead to a more informed assessment of subjective levels of deconditioning, as well as assist in the appropriate matching of controls with CFS subjects.

Increased afferent feedback and consequent gain in effort sense may also be related to the presence of a low-grade infections, noted by Gibson et al. (1993) to be evident in 53% of

patients diagnosed with post viral fatigue syndrome (a subset of CFS). As all CFS subjects in this study had their disorder triggered by an infection, the presence of low-grade infections may have contributed to an abnormal sense of effort in these subjects.

A gain in effort sense as a consequent of a disproportionate mismatch between neural signals, may be further amplified by a lower sensory threshold in CFS patients (Gibson et al. 1993), as well as an increased detection threshold for force (Jones, 1995). A lowered sensory threshold implies that attention to the amplitude of the corollary discharge may occur earlier in CFS subjects relative to controls, while an increased detection threshold for force suggests that CFS subjects detect force earlier than controls with a concomitant increase in afferent feedback. Gibson et al. (1993, p. 997) suggest that the resetting of the sensory threshold "may be a learned response to stimuli no longer present," while an increased detection threshold has been demonstrated during prolonged exposure to fatiguing sounds, as well as to visual and olfactory stimuli (Jones, 1995).

5.6 Conclusion

This study demonstrated that force and rmsEMG were not statistically different between CFS and control subjects during a fatiguing contralateral limb matching task. However, comparison of normalised mean matching forces for each time interval during the fatiguing task, confirmed that the CFS group produced greater force than controls when attempting to match a low-level isometric force of the reference arm. This increased matching force, which was most noticeable in the last five minutes of the protocol, was paralleled by matching rmsEMG activity, as well as higher rmsEMG in the reference arm of CFS subjects. These trends suggest that a more fatiguing protocol or a larger cohort may have produced statistically significant results. Overestimation of matching force during a

contralateral limb matching task objectively demonstrates attention to central mediators for sense of effort. While increased matching force with a concomitant increase in effort sense in the CFS group relative to the control group were not statistically supported, a greater sense of effort was subjectively confirmed by significantly higher RPE scores reported by the CFS group, both prior to and during exercise.

Elevated RPE scores reported prior to exercise suggest that peripheral fatigue is unlikely to account for the fatigue experienced in CFS, while normal MVC values (as demonstrated by comparison to controls) precludes excessive and premature central mediators for fatigue. Normal muscle physiology evident in CFS subjects would imply that the regular application of a neurophysiological definition to the fatigue experienced in this disorder may be inappropriate and need reassessing. Possibly, central mediators for sense of effort may better define the fatigue experienced in CFS.

Improvements to research in the area investigated in this study, include the following:

1 Larger cohorts would produce results that are more representative of the population.

2 Testing of CFS subjects whose condition was triggered by factors other than an infectious episode. This would test to see if all CFS subsets responded to a fatiguing task in the same manner.

3 Recording and correlation of RPE values and POMS responses during recovery. This would provide insight into the fatigue experienced by CFS subjects after exercise, as well as determine if any association exists between these two parameters.

4 Employment of twitch interpolation techniques in order to provide for objective determination of the attainment of MVC in all subjects.

5 Employment of a more fatiguing task. A task that promotes greater fatigue may validate trends. The task can be made more fatiguing by increasing the length of the protocol by five to ten minutes, by reducing rest periods from three seconds to two, or by increasing the reference force. Stevens and Cain (1970) note that effort relating to constant force contractions increases with time at a rate dependent on the level of the reference force.

6 Employment of a scale that measures subjective levels of pain. Use of such a scale during a fatiguing task, would indicate if CFS subjects were experiencing greater levels of pain than controls. Higher pain levels may induce central fatigue or amplify afferent feedback, resulting in a consequent gain in effort sense.

7 Employment of a questionnaire concerned with activity level prior to onset of CFS, as well as the time period of any inactivity. This information will assist in determining the impact of deconditioning on effort sense.

8 Assessment of aerobic capacity prior to testing will assist in assessing subjective levels of deconditioning, as well as aid in appropriately matching controls with CFS subjects.

CFS represents a topical syndrome that in recent times has featured regularly in newspaper and magazine articles. More often than not, reference is made to the elite sportsperson whose career has suffered as a consequence of the disorder. Rarely mentioned are the numerous 'ordinary' people whose lives have suffered dramatically as a result of this debilitating illness. Lack of consensus regarding aetiology, combined with dissension concerning the origin of the fatigue that typifies the disorder, present a strong case for further research in this field.

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Appendix A

Criteria for Diagnosis of CFS

Criteria for diagnosis for chronic fatigue syndrome (Jain &DeLisa, 1998)

Major Criteria's (both must be present)	**Minor Criteria** (at least 8 symptoms and 2 signs)	**Physical Signs**
1. Onset of persistent or relapsing, debilitating fatigue in a person without a previous history of such symptoms, that does not resolve with bed rest and is severe enough to significantly reduce daily activity for at least 6 months. 2. Fatigue that is not explained by the present of other evident medical or psychiatric illness.	Infectious: Mild fever of chills Sore throat: Painful adenopathy Rheumatologic: Unexplained, generalised muscle weakness Myalgias, migratory arthalgia, without swelling or erythremia Prolonged generalised fatigue after previously tolerated physical activity Migratory arthralgia without swelling or redness Neuropsychologic Recurrent generalised headache, depression Sleep disturbances Impaired cognition Anxiety Photophobia Transient scotoma Main symptom complex Developing over a few hours to a few days	Low-grade fever Nonexudative pharyngitis Palpable or tender anterior or posterior cervical or axillary lymph nodes.

Appendix B

Consent Form

Consent Form for Participation in the Investigation into
"Sense of Effort Associated with Fatigue in Chronic Fatigue Syndrome Patients"

The purpose of this study is to investigate the sense of effort experienced by Chronic Fatigue Syndrome subjects when performing a prolonged sub-maximal intermittent contraction.

We will test the strength of your elbow flexor muscles by asking you to perform a brief maximal static contraction. You will then be asked to hold a light contraction intermittently for 45 minutes. At this point the exercise will be terminated. During the contraction, you will be asked to match the force in the non-dominant arm with your dominant arm for a period of 7 seconds every minute. We will also ask you to rate your perceived effort on a number scale. Throughout this procedure, the electrical activity (EMG) generated by your muscles will be monitored using surface pads.

The above protocol will be clearly demonstrated and you will have a chance to practice before the testing commences. Some slight delayed soreness may be experienced in the exercised arm 24 – 48 hours after the testing day, similar to that which you might experience when you first exercise after a break. Subjects with Chronic Fatigue Syndrome may experience increased tiredness after performing the exercise.

The results gained from this research may be used to further our insight into how sense of effort is altered when our muscles are fatigued.

Having read the above statements, I acknowledge that I am able to withdraw from the study at any time and am aware of the possible side effects that may occur. I also release Edith Cowan University and the Australian Neuromuscular Research Institute from any claim arising from experimental procedures.

For further information please contact either Mrs K. Wallman on [redacted] or Dr. P. Sacco on [redacted].

I ...., aged ....years, agree to participate as a subject in the above study.

Signed ....   Date ....

Witnessed ....   Date ....

Appendix C

Activity Sheet

Personal Activity Sheet

NAME: .... SUBURB: ....
CONTACT PHONE NO: ....
CONVENIENT CONTACT TIME: ....
AGE: .... HEIGHT: .... WEIGHT: ....

Please complete the following record of you average weekly exercise participation. This refers to specific exercise such as walking and fitness classes as opposed to exercise that occurs due to shopping, work around the house, etc. Please circle the number closest to the correct response.

Frequency	5	Daily or almost daily
	4	3 to 5 times per week
	3	1 to 2 times per week
	2	A few times per month
	1	Less than once per month

Intensity	5	Sustained heavy breathing and perspiration (extremely hard)
	4	Heavy breathing and perspiration (moderate to hard)
	3	Moderately heavy breathing as in brisk walking (moderate)
	2	Moderately heavy breathing as in casual walking (light/moderate)
	1	Very easy as in stretching (light)

Time	4	Over 30 minutes
	3	20 to 30 minutes
	2	10 to 20 minutes
	1	Under 10 minutes

Do you do any upper body work? If yes give details of how often per week ....

Office Information Only

Subjects are classified by multiplying frequency x intensity x time.

General classification

5-25	Sedentary
25-55	Moderate
55-100	Highly active

Appendix D

Medical Questionnaire

Medical History Questionnaire

This is to establish a background for your personal health and any recent or current injuries or illnesses that may affect your testing or performance. Please answer questions as accurately as possible. All information is strictly confidential.

Name : ____

Sex (please tick) Male __________ Female __________

Age : _______ Weight : _______ Best/desired weight: __________

Name of Family Doctor: ____________________________

Address of Family Doctor: ____________________________

____

Phone No. of Family Doctor: ______________________

Name for Emergency Contact: ______________________

Emergency Contact's phone no.: ______________________

Do you currently have or have had any of the following?

	(Please Circle)	
High or abnormal blood pressure	Y	N
High cholesterol/triglycerides	Y	N
Rheumatic fever	Y	N
Any known abnormal heart condition	Y	N
Asthma	Y	N
Diabetes	Y	N
Back pain	Y	N

Neck pain	Y	N
Allergies	Y	N
Have you recently had any infectious diseases (include flu)?	Y	N
Are you pregnant?	Y	N
Are you taking Beta -blocker drugs?	Y	N
Are you taking any other drugs/medication	Y	N
Are you on a special diet?	Y	N
Is there any other condition not mentioned that may affect your activities?	Y	N

If you answered yes to any of the above questions, please give more details in the space provided below.

Have you experienced any of the following?

Any recent injuries, accidents or illnesses?	Y	N
Any recurring muscular pains/cramps?	Y	N

If you answered yes to either of these questions, please give more details in the space provided.

Family History

Are any of the following known to exist in your family?

Cardiac disease	Y	N
Pulmonary disease	Y	N
Stroke	Y	N
Sudden death (unexplained)	Y	N

Lifestyle Habits

Do you exercise regularly? Y N

If yes, how many minutes of medium to high intensity exercise per week? ______________________

Do you smoke tobacco or any other nicotine products? Y N

If you answered No and were once a smoker, how long since quitting? ________________

Do you consume alcohol? Y N

How many standard drinks per week? ________________

Do you consume tea and/or coffee? Y N

How many cups per day? ______________

Do you take recreational (steroid/party) drugs? Y N

How often/much per week? ______________

Should any obvious physical signs of distress occur during testing, the session will be terminated

Appendix E

POMS Questionnaire

NAME ____________________ DATE __________

SEX: Male (M) Female (F)

IDENTIFICATION

Below is a list of words that describe feelings people have. Please read each one carefully. Then fill in ONE circle under the answer to the right which best describes HOW YOU HAVE BEEN FEELING DURING THE PAST WEEK INCLUDING TODAY.

The numbers refer to these phrases.

0 = Not at all
1 = A little
2 = Moderately
3 = Quite a bit
4 = Extremely

Col (C) O.P. (O)

Item	NOT AT ALL	A LITTLE	MODERATELY	QUITE A BIT	EXTREMELY
1. Friendly	0	1	2	3	4
2. Tense	0	1	2	3	4
3. Angry	0	1	2	3	4
4. Worn out	0	1	2	3	4
5. Unhappy	0	1	2	3	4
6. Clear-headed	0	1	2	3	4
7. Lively	0	1	2	3	4
8. Confused	0	1	2	3	4
9. Sorry for things done	0	1	2	3	4
10. Shaky	0	1	2	3	4
11. Listless	0	1	2	3	4
12. Peeved	0	1	2	3	4
13. Considerate	0	1	2	3	4
14. Sad	0	1	2	3	4
15. Active	0	1	2	3	4
16. On edge	0	1	2	3	4
17. Grouchy	0	1	2	3	4
18. Blue	0	1	2	3	4
19. Energetic	0	1	2	3	4
20. Panicky	0	1	2	3	4
21. Hopeless	0	1	2	3	4
22. Relaxed	0	1	2	3	4
23. Unworthy	0	1	2	3	4
24. Spiteful	0	1	2	3	4
25. Sympathetic	0	1	2	3	4
26. Uneasy	0	1	2	3	4
27. Restless	0	1	2	3	4
28. Unable to concentrate	0	1	2	3	4
29. Fatigued	0	1	2	3	4
30. Helpful	0	1	2	3	4
31. Annoyed	0	1	2	3	4
32. Discouraged	0	1	2	3	4
33. Resentful	0	1	2	3	4
34. Nervous	0	1	2	3	4
35. Lonely	0	1	2	3	4
36. Miserable	0	1	2	3	4
37. Muddled	0	1	2	3	4
38. Cheerful	0	1	2	3	4
39. Bitter	0	1	2	3	4
40. Exhausted	0	1	2	3	4
41. Anxious	0	1	2	3	4
42. Ready to fight	0	1	2	3	4
43. Good natured	0	1	2	3	4
44. Gloomy	0	1	2	3	4
45. Desperate	0	1	2	3	4
46. Sluggish	0	1	2	3	4
47. Rebellious	0	1	2	3	4
48. Helpless	0	1	2	3	4
49. Weary	0	1	2	3	4
50. Bewildered	0	1	2	3	4
51. Alert	0	1	2	3	4
52. Deceived	0	1	2	3	4
53. Furious	0	1	2	3	4
54. Efficient	0	1	2	3	4
55. Trusting	0	1	2	3	4
56. Full of pep	0	1	2	3	4
57. Bad-tempered	0	1	2	3	4
58. Worthless	0	1	2	3	4
59. Forgetful	0	1	2	3	4
60. Carefree	0	1	2	3	4
61. Terrified	0	1	2	3	4
62. Guilty	0	1	2	3	4
63. Vigorous	0	1	2	3	4
64. Uncertain about things	0	1	2	3	4
65. Bushed	0	1	2	3	4

MAKE SURE YOU HAVE ANSWERED EVERY ITEM.

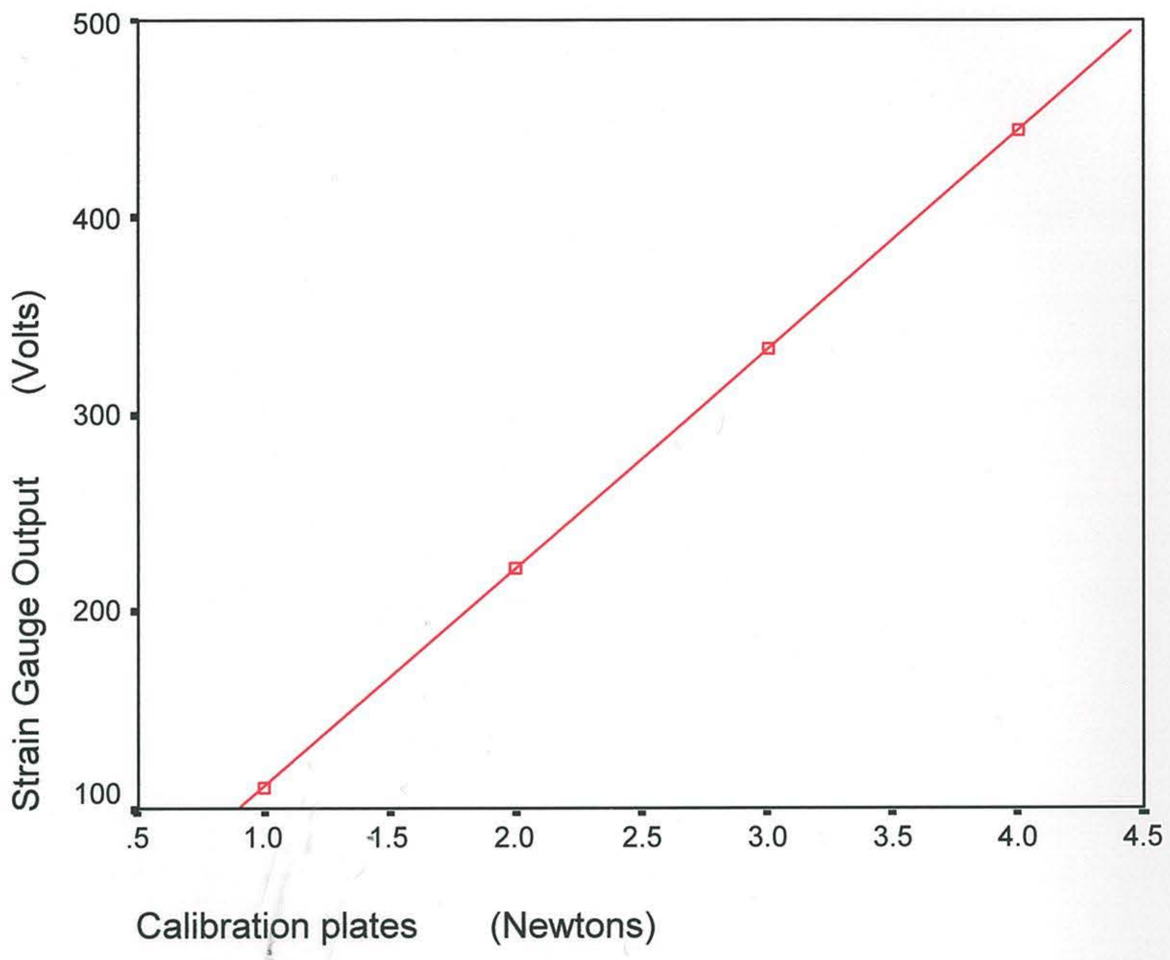
POM 021

Appendix F

Calibration Details

Appendix F

Linear Regression for Calibration of Strain Gauge.



Calibration of strain gauge using fixed plates (N). Each fixed plate weighed 11.34 kg, (111.245 N). .

Appendix G

RPE Data Collection Sheet

RPE Data Information Table

Subject No: ....

Age ....

Weight ....

MVC (Dominant Arm) ....

(Note whether left or right is dominant arm)

MVC (Non Dominant Arm) ....

Non Dominant Arm

70% ....

50% ....

30% ....

Dominant Arm

70% ....

50% ....

30% ....

Time (mins)	RPE	Comments	Time (mins)	RPE	Comments
1			25		
2			26		
3			27		
4			28		
5			29		
6			30		
7			31		
8			32		
9			33		
10			34		
11			35		
12			36		
13			37		
14			38		
15			39		
16			40		
17			41		
18			42		
19			43		
20			44		
21			45		
22			R – 1		
23			R – 3		
24			R – 5		
			R – 10		

Appendix H

Cr-10 Scale

CR-10 Scale

0	- Nothing at all	
0.5	- Very, very weak	(just noticeable)
1	- Very weak	
2	- Weak	(light)
3	- Moderate	
4	- Somewhat strong	
5	- Strong	(heavy)
6	-	
7	- Very strong	
8	-	
9	-	
10	- Very, very strong	(almost max)
•	- Maximal	

Source: Borg, G. (1982). Psychological bases of perceived exertion. Medicine and Science in Sports and Exercise, 14 (5), 377-381.

Appendix I

Results for Pilot Study

Pilot Study

	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
Averaged Force Recording in Left Arm (newtons)										
MVC (best)	238	241	314	318	310	324	471	415	434	373
80% of MVC	185	191	244	257	242	270	361	334	351	292
60% of MVC	142	138	180	192	180	200	285	242	251	222
40% of MVC	92	88	124	131	123	136	184	168	175	152
20% of MVC	47	45	60	65	59	71	94	86	89	76
Averaged Force recording in Right Arm (newtons)										
MVC (Best)	229	242	370	360	319	344	341	342	363	372
80% of MVC	183	195	293	295	249	275	273	265	294	285
60% of MVC	137	145	221	218	194	210	208	206	176	186
40% of MVC	91	99	148	145	127	140	140	135	151	152
20% of MVC	47	49	71	73	64	70	92	75	76	69
Averaged EMG Recording in Left Arm										
MVC (best)	0.180	0.133	0.121	0.168	0.389	0.325	0.278	0.303	0.283	0.276
80% of MVC	0.136	0.096	0.100	0.146	0.227	0.209	0.200	0.236	0.158	0.135
60% of MVC	0.092	0.093	0.088	0.133	0.184	0.125	0.165	0.192	0.060	0.072
40% of MVC	0.089	0.048	0.085	0.059	0.081	0.078	0.078	0.100	0.047	0.060
20% of MVC	0.050	0.038	0.048	0.045	0.075	0.037	0.048	0.045	0.028	0.021
Averaged EMG Recording in Right Arm										
MVC (best)	0.169	0.138	0.248	0.273	0.281	0.300	0.219	0.210	0.183	0.210
80% of MVC	0.132	0.120	0.190	0.232	0.153	0.142	0.196	0.152	0.157	0.188
60% of MVC	0.083	0.076	0.136	0.186	0.132	0.094	0.137	0.149	0.073	0.140
40% of MVC	0.064	0.054	0.102	0.122	0.077	0.062	0.074	0.102	0.071	0.086
20% of MVC	0.030	0.028	0.020	0.026	0.025	0.036	0.039	0.037	0.035	0.052

PILOT STUDY

Statistics for 80% MVC

80% MVC - Force -Left Arm

	Test 1	Test 2	Difference
Subject 1	185	191	-6
Subject 2	244	257	-13
Subject 3	242	270	-28
Subject 4	361	334	27
Subject 5	351	292	59
Mean	276.60	268.80	7.80
SD	76.34	52.40	34.98
Method Error*			24.74
Coefficient Variation (%)			9.1
Correlation			0.92
Squared Correlation Coefficient (%)			84

80% MVC - Force -Right Arm

	Test 1	Test 2	Difference
Subject 1	183	195	-12
Subject 2	293	295	-2
Subject 3	249	275	-26
Subject 4	273	265	8
Subject 5	294	285	9
Mean	258.40	263.00	-4.60
SD	45.97	39.62	14.69
Method Error*			10.39
Coefficient Variation (%)			3.6
Correlation			0.95
Squared Correlation Coefficient (%)			91

80% MVC - EMG - Left Arm

	Test 1	Test 2	Difference
Subject 1	0.136	0.096	0.04
Subject 2	0.100	0.146	-0.046
Subject 3	0.227	0.209	0.018
Subject 4	0.200	0.236	-0.036
Subject 5	0.158	0.135	0.023
Mean	0.164	0.164	0.000
SD	0.050	0.057	0.038
Method Error*			0.027
Coefficient Variation (%)			16.5
Correlation			0.75
Squared Correlation Coefficient (%)			57

80% MVC- EMG- Right Arm

	Test 1	Test 2	Difference
Subject 1	0.132	0.120	0.012
Subject 2	0.190	0.232	-0.042
Subject 3	0.152	0.142	0.01
Subject 4	0.196	0.152	0.044
Subject 5	0.157	0.188	-0.031
Mean	0.165	0.167	-0.001
SD	0.027	0.044	0.035
Method Error*			0.025
Coefficient Variation (%)			14.9
Correlation			0.61
Squared Correlation Coefficient (%)			37

* Method Error formula from Thorstensson, 1976 (cited in MacDougall, Wenger & Green, 1991, p. 76).

PILOT STUDY

Statistics for 40% MVC

40% MVC - Force -Left Arm

	Test 1	Test 2	Difference
Subject 1	92	88	4
Subject 2	124	131	-7
Subject 3	123	136	-13
Subject 4	184	168	16
Subject 5	175	152	23
Mean	139.60	135.00	4.60
SD	38.76	30.02	15.11
Method Error*			10.68
Coefficient Variation (%)			7.8
Correlation			0.93
Squared Correlation Coefficient (%)			87

40% MVC - Force -Right Arm

	Test 1	Test 2	Difference
Subject 1	91	99	-8
Subject 2	148	145	3
Subject 3	127	140	-13
Subject 4	140	135	5
Subject 5	151	152	-1
Mean	131.40	134.20	-2.80
SD	24.42	20.66	7.56
Method Error*			5.35
Coefficient Variation (%)			3.5
Correlation			0.96
Squared Correlation Coefficient (%)			92

40% MVC - EMG - Left Arm

	Test 1	Test 2	Difference
Subject 1	0.089	0.048	0.041
Subject 2	0.085	0.059	0.026
Subject 3	0.081	0.078	0.003
Subject 4	0.078	0.100	-0.022
Subject 5	0.047	0.060	-0.013
Mean	0.076	0.069	0.007
SD	0.017	0.020	0.026
Method Error*			0.019
Coefficient Variation (%)			25.7
Correlation			0.004
Squared Correlation Coefficient			0.001

40% MVC- EMG- Right Arm

	Test 1	Test 2	Difference
Subject 1	0.064	0.054	0.01
Subject 2	0.102	0.122	-0.02
Subject 3	0.077	0.062	0.015
Subject 4	0.074	0.102	-0.028
Subject 5	0.071	0.086	-0.015
Mean	0.078	0.085	-0.008
SD	0.014	0.028	0.019
Method Error*			0.013
Coefficient Variation (%)			16.5
Correlation			0.78
Squared Correlation Coefficient			61

* Method Error formula from Thorstensson, 1976 (cited in MacDougall, Wenger & Green, 1991, p. 76).

PILOT STUDY

Statistics for 60% MVC

60% MVC - Force -Left Arm

	Test 1	Test 2	Difference
Subject 1	142	138	4
Subject 2	180	192	-12
Subject 3	180	200	-20
Subject 4	285	242	43
Subject 5	251	222	29
Mean	207.60	198.80	8.80
SD	58.53	39.21	26.75
Method Error*			18.92
Coefficient Variation (%)			9.3
Correlation			0.93
Squared Correlation Coefficient (%)			86

60% MVC - Force -Right Arm

	Test 1	Test 2	Difference
Subject 1	137	145	-8
Subject 2	221	218	3
Subject 3	194	210	-16
Subject 4	208	206	2
Subject 5	176	186	-10
Mean	187.20	193.00	-5.80
SD	32.66	29.31	8.14
Method Error*			5.75
Coefficient Variation (%)			3.2
Correlation			0.97
Squared Correlation Coefficient (%)			94

60% MVC - EMG - Left Arm

	Test 1	Test 2	Difference
Subject 1	0.092	0.093	-0.001
Subject 2	0.088	0.133	-0.045
Subject 3	0.184	0.125	0.059
Subject 4	0.165	0.192	-0.027
Subject 5	0.060	0.072	-0.012
Mean	0.118	0.123	-0.005
SD	0.054	0.046	0.040
Method Error*			0.028
Coefficient Variation (%)			23.2
Correlation			0.69
Squared Correlation Coefficient			48

60% MVC- EMG- Right Arm

	Test 1	Test 2	Difference
Subject 1	0.083	0.076	0.007
Subject 2	0.136	0.186	-0.050
Subject 3	0.132	0.094	0.038
Subject 4	0.137	0.149	-0.012
Subject 5	0.073	0.140	-0.067
Mean	0.112	0.129	-0.017
SD	0.031	0.044	0.042
Method Error*			0.030
Coefficient Variation (%)			24.9
Correlation			0.41
Squared Correlation Coefficient			17

* Method Error formula from Thorstensson, 1976 (cited in MacDougall, Wenger & Green, 1991, p. 76).

PILOT STUDY

Statistics for 20% MVC

20% MVC - Force -Left Arm

	Test 1	Test 2	Difference
Subject 1	47	45	2
Subject 2	60	65	-5
Subject 3	59	71	-12
Subject 4	94	86	8
Subject 5	89	76	13
Mean	69.80	68.60	1.20
SD	20.54	15.27	9.98
Method Error*			7.06
Coefficient Variation (%)			10.2
Correlation			0.89
Squared Correlation Coefficient (%)			78

20% MVC - Force -Right Arm

	Test 1	Test 2	Difference
Subject 1	47	49	-2
Subject 2	71	73	-2
Subject 3	64	70	-6
Subject 4	92	75	17
Subject 5	76	69	7
Mean	70.00	67.20	2.80
SD	16.48	10.45	9.26
Method Error*			6.55
Coefficient Variation (%)			9.0
Correlation			0.86
Squared Correlation Coefficient (%)			73

20% MVC - EMG - Left Arm

	Test 1	Test 2	Difference
Subject 1	0.050	0.038	0.012
Subject 2	0.048	0.045	0.003
Subject 3	0.075	0.037	0.038
Subject 4	0.048	0.045	0.003
Subject 5	0.028	0.021	0.007
Mean	0.050	0.037	0.013
SD	0.017	0.010	0.015
Method Error*			0.010
Coefficient Variation (%)			23.9
Correlation			0.49
Squared Correlation Coefficient			24

20% MVC- EMG- Right Arm

	Test 1	Test 2	Difference
Subject 1	0.030	0.028	0.002
Subject 2	0.020	0.026	-0.006
Subject 3	0.025	0.036	-0.011
Subject 4	0.039	0.037	0.002
Subject 5	0.035	0.052	-0.017
Mean	0.030	0.036	-0.006
SD	0.008	0.010	0.008
Method Error*			0.006
Coefficient Variation (%)			17.8
Correlation			0.61
Squared Correlation Coefficient			37

* Method Error formula from Thorstensson, 1976 (cited in MacDougall, Wenger & Green, 1991, p. 76).

Appendix J

Results for Formal Testing

Raw and Normalised Data & Statistical Results

CFS 1

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	262	100	234	100	0.2	100	0.191	100
70%	8	92	35	163	70	0.07	35	0.15	79
50%	7	76	29	117	50	0.05	25	0.11	58
30%	3	43	16	70	30	0.05	25	0.06	31
Endurance									
1	2	28	11	65	28	0.024	12	0.039	20
2	2	35	13	70	30	0.033	17	0.048	25
3	2	35	13	69	29	0.023	12	0.044	23
4	2	40	15	70	30	0.023	12	0.032	17
5	3								
6	3	52	20	69	29	0.025	13	0.032	17
7	3	35	13	71	30	0.033	17	0.039	20
8	3	24	9	70	30	0.035	18	0.033	17
9	3	29	11	69	29	0.03	15	0.033	17
10	3								
11	3	38	15	70	30	0.029	15	0.042	22
12	4	37	14	71	30	0.04	20	0.044	23
13	4	50	19	69	29	0.036	18	0.05	26
14	4	49	19	70	30	0.031	16	0.042	22
15	4								
16	4	52	20	70	30	0.035	18	0.032	17
17	5	42	16	69	29	0.039	20	0.031	16
18	5	62	24	70	30	0.04	20	0.038	20
19	5	60	23	71	30	0.036	18	0.046	24
20	5								
21	6	46	18	70	30	0.033	17	0.045	24
22	6	49	19	68	29	0.033	17	0.038	20
23	6	48	18	69	29	0.034	17	0.038	20
24	7	33	13	70	30	0.03	15	0.04	21
25	7								
26	7	51	19	71	30	0.026	13	0.038	20
27	7	60	23	70	30	0.028	14	0.042	22
28	8	71	27	71	30	0.038	19	0.049	26
29	8	43	16	73	31	0.034	17	0.04	21
30	8								
31	8	35	13	71	30	0.052	26	0.036	19
32	8	52	20	70	30	0.057	29	0.04	21
33	8	45	17	71	30	0.036	18	0.04	21
34	8	47	18	69	29	0.041	21	0.038	20
35	9								
36	9	46	18	70	30	0.044	22	0.044	23
37	9	46	18	73	31	0.035	18	0.058	30
38	9	47	18	71	30	0.044	22	0.039	20
39	10	60	23	70	30	0.042	21	0.048	25
40	10								
41	10	55	21	69	29	0.038	19	0.049	26
42	10	56	21	70	30	0.041	21	0.059	31
43	10	64	24	71	30	0.039	20	0.055	29
44	10	66	25	67	29	0.062	31	0.066	35
45	10								
Recovery									
1		36	14	70	30	0.051	26	0.033	17
3		61	23	68	29	0.029	15	0.031	16
5		65	25	71	30	0.03	15	0.035	18
10		54	21	69	29	0.043	22	0.032	17

CFS 2

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	146	100	143	100	0.065	100	0.067	100
70%	8	97	66	100	70	0.039	60	0.057	85
50%	6	71	49	71.5	50	0.032	49	0.036	54
30%	3	58	40	43	30	0.021	32	0.025	37
Endurance									
1	3	28	19	49	34	0.018	28	0.025	37
2	3	31	21	42	29	0.021	32	0.024	36
3	4	43	29	45	31	0.02	31	0.026	39
4	4	43	29	42	29	0.019	29	0.023	34
5	4								
6	4	52	36	42	29	0.022	34	0.025	37
7	5	58	40	44	31	0.026	40	0.025	37
8	5	51	35	43	30	0.024	37	0.025	37
9	5	46	32	44	31	0.023	35	0.023	34
10	6								
11	6	43	29	43	30	0.022	34	0.023	34
12	7	58	40	44	31	0.023	35	0.026	39
13	6	51	35	43	30	0.023	35	0.025	37
14	6	46	32	42	29	0.021	32	0.025	37
15	7								
16	7	34	23	42	29	0.022	34	0.022	33
17	7	43	29	45	31	0.024	37	0.022	33
18	7	42	29	44	31	0.021	32	0.023	34
19	7	59	40	44	31	0.025	38	0.025	37
20	8								
21	8	41	28	43	30	0.024	37	0.023	34
22	8	52	36	46	32	0.027	42	0.023	34
23	8	44	30	44	31	0.021	32	0.024	36
24	8	43	29	44	31	0.023	35	0.024	36
25	8								
26	8	36	25	43	30	0.025	38	0.022	33
27	8	31	21	42	29	0.022	34	0.022	33
28	8	36	25	44	31	0.023	35	0.026	39
29	8.5	45	31	43	30	0.023	35	0.027	40
30	8.5								
31	8.5	48	33	43	30	0.022	34	0.028	42
32	8.5	45	31	43	30	0.023	35	0.026	39
33	8.5	40	27	43	30	0.025	38	0.025	37
34	8.5	42	29	42	29	0.022	34	0.026	39
35	9								
36	9	49	34	42	29	0.027	42	0.03	45
37	9	42	29	41	29	0.026	40	0.035	52
38	9	46	32	44	31	0.031	48	0.036	54
39	9	38	26	41	29	0.028	43	0.034	51
40	10								
41	10	50	34	44	31	0.026	40	0.035	52
42	10	57	39	42	29	0.031	48	0.032	48
43	11	66	45	42	29	0.028	43	0.033	49
44	11	67	46	44	31	0.03	46	0.037	55
45	11								
Recovery									
1		53	36	40	28	0.031	48	0.025	37
3		48	33	41	29	0.027	42	0.025	37
5		53	36	44	31	0.027	42	0.026	39
10		51	35	41	29	0.028	43	0.027	40

CFS 3

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	498	100	481	100	0.38	100	0.32	100
70%	7	287	58	336	70	0.23	61	0.22	69
50%	5	258	52	240	50	0.14	37	0.12	38
30%	3	170	34	144	30	0.063	17	0.068	21
Endurance									
1	3	128	26	144	30	0.045	12	0.05	16
2	3	144	29	143	30	0.046	12	0.051	16
3	3	141	28	143	30	0.055	14	0.05	16
4	5	222	45	143	30	0.06	16	0.046	14
5	5								
6	5	185	37	144	30	0.056	15	0.045	14
7	5	186	37	145	30	0.06	16	0.046	14
8	5	187	38	145	30	0.068	18	0.046	14
9	5	166	33	146	30	0.06	16	0.048	15
10	6								
11	6	169	34	145	30	0.066	17	0.05	16
12	6	150	30	145	30	0.064	17	0.045	14
13	7	165	33	146	30	0.067	18	0.046	14
14	8	192	39	142	30	0.064	17	0.046	14
15	8								
16	8	244	49	145	30	0.06	16	0.046	14
17	8	227	46	147	31	0.068	18	0.047	15
18	8	222	45	147	31	0.056	15	0.045	14
19	9	182	37	144	30	0.055	14	0.046	14
20	9								
21	9	178	36	144	30	0.058	15	0.048	15
22	10	197	40	148	31	0.06	16	0.047	15
23	10	173	35	144	30	0.059	16	0.042	13
24	10	195	39	145	30	0.066	17	0.047	15
25	10								
26	9	222	45	146	30	0.069	18	0.049	15
27	9	192	39	145	30	0.07	18	0.047	15
28	9	192	39	145	30	0.071	19	0.048	15
29	9	210	42	145	30	0.069	18	0.046	14
30	9								
31	10	206	41	143	30	0.075	20	0.049	15
32	10	248	50	144	30	0.077	20	0.048	15
33	10	250	50	145	30	0.069	18	0.046	14
34	10	231	46	144	30	0.073	19	0.056	18
35	10								
36	10	282	57	146	30	0.11	29	0.052	16
37	10	206	41	144	30	0.091	24	0.052	16
38	10	212	43	143	30	0.094	25	0.059	18
39	11	226	45	144	30	0.09	24	0.062	19
40	11								
41	11	277	56	142	30	0.1	26	0.061	19
42	11	287	58	148	31	0.12	32	0.066	21
43	11	297	60	147	31	0.12	32	0.075	23
44	11	261	52	145	30	0.13	34	0.088	28
45	11								
Recovery									
1		218	44	145	30	0.088	23	0.09	28
3		263	53	144	30	0.087	23	0.078	24
5		215	43	144	30	0.073	19	0.072	23
10		189	38	143	30	0.087	23	0.072	23

CFS 4

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	242	100	237	100	0.142	100	0.07	100
70%	8	166	69	165	70	0.09	63	0.064	91
50%	6	88	36	118	50	0.06	42	0.056	80
30%	4	53	22	71	30	0.032	23	0.039	56
Endurance									
1	3	28	12	73	31	0.025	18	0.034	49
2	3	29	12	74	31	0.024	17	0.037	53
3	4	53	22	73	31	0.031	22	0.037	53
4	4	37	15	72	30	0.03	21	0.039	56
5	5								
6	5	36	15	71	30	0.031	22	0.037	53
7	5	41	17	72	30	0.033	23	0.037	53
8	4	41	17	74	31	0.033	23	0.037	53
9	4	58	24	72	30	0.039	27	0.039	56
10	5								
11	5	42	17	74	31	0.037	26	0.039	56
12	5	46	19	71	30	0.038	27	0.037	53
13	5	42	17	71	30	0.038	27	0.038	54
14	5	73	30	74	31	0.044	31	0.042	60
15	5								
16	5	63	26	70	30	0.04	28	0.039	56
17	5	58	24	71	30	0.038	27	0.035	50
18	6	60	25	73	31	0.038	27	0.037	53
19	6	62	26	73	31	0.039	27	0.039	56
20	6								
21	6	60	25	70	30	0.038	27	0.038	54
22	6	55	23	75	32	0.039	27	0.039	56
23	6	68	28	72	30	0.039	27	0.039	56
24	6	70	29	73	31	0.039	27	0.04	57
25	7								
26	7	50	21	73	31	0.038	27	0.04	57
27	7	52	21	72	30	0.04	28	0.039	56
28	7	62	26	73	31	0.044	31	0.04	57
29	7	56	23	73	31	0.04	28	0.04	57
30	8								
31	8	55	23	74	31	0.032	23	0.039	56
32	8	60	25	72	30	0.04	28	0.04	57
33	8	70	29	71	30	0.044	31	0.042	60
34	8	67	28	72	30	0.045	32	0.042	60
35	9								
36	9	52	21	73	31	0.044	31	0.045	64
37	9	61	25	72	30	0.043	30	0.044	63
38	9	70	29	73	31	0.042	30	0.045	64
39	10	73	30	72	30	0.048	34	0.047	67
40	10								
41	10	53	22	73	31	0.041	29	0.044	63
42	10	86	36	71	30	0.05	35	0.047	67
43	10	78	32	72	30	0.047	33	0.045	64
44	10	73	30	72	30	0.046	32	0.042	60
45	10								
Recovery									
1		77	32	72	30	0.05	35	0.05	71
3		57	24	74	31	0.052	37	0.054	77
5		87	36	72	30	0.04	28	0.054	77
10		82	34	73	31	0.031	22	0.053	76

CFS 5

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	366	100	348	100	0.090	100	0.188	100
70%	8	100	27	244	70	0.045	50	0.085	45
50%	7	117	32	174	50	0.050	56	0.049	26
30%	5	85	23	105	30	0.034	38	0.056	30
Endurance									
1	4	138	38	106	30	0.037	41	0.028	15
2	4	181	49	99	28	0.058	64	0.032	17
3	5	83	23	102	29	0.048	53	0.017	9
4	5	79	22	106	30	0.026	28	0.015	8
5	6								
6	6	73	20	101	29	0.026	28	0.030	16
7	6	48	13	104	30	0.021	23	0.027	14
8	7	43	12	104	30	0.018	20		0
9	7	58	16	102	29	0.019	21	0.023	12
10	7								
11	7	74	20	98	28	0.013	14	0.033	18
12	7	68	19	103	30	0.020	22	Invalid	
13	7	92	25	106	30	0.021	23		
14	7	32	9	104	30	0.022	24		
15	7								
16	7	42	11	110	32	0.028	31		
17	7	46	13	103	30	0.039	43	0.026	14
18	7	77	21	97	28	Invalid			
19	8	83	23	104	30			0.027	14
20	8								
21	8	97	27	101	29	0.024	27	0.034	18
22	8	76	21	105	30	0.044	49		
23	8	78	21	104	30	0.020	22		
24	8	97	27	105	30	0.025	28	0.031	16
25	9								
26	8	75	20	101	29	0.022	25	0.026	14
27	9	127	35	102	29	0.021	23	0.020	11
28	9	56	15	106	30	0.025	28		
29	9	80	22	101	29	0.018	20	0.032	17
30	10								
31	10	78	21	103	30	0.032	35		
32	10	91	25	102	29	0.030	33	0.018	10
33	9	67	18	106	30	0.032	36	0.035	19
34	9	83	23	105	30	0.024	27	0.035	19
35	9								
36	9	85	23	110	32	0.032	35	0.025	13
37	10	100	27	103	30	0.030	33	0.052	27
38	10	90	25	101	29	0.033	36	0.038	20
39	10	104	28	105	30	0.024	27	0.031	16
40	11								
41	11	114	31	102	29	Invalid		Invalid	
42	11	148	40	103	30				
43	11	133	36	104	30				
44	11	176	48	102	29				
45	11								
Recovery									
1	8	123	34	103	30	Invalid		Invalid	
3	7	122	33	102	29				
5	6	Missed			0				
10	6	118	32	105	30				

CFS 6

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	410	100	378	100	0.19	100	0.24	100
70%	6	213	52	263	70	0.12	63	0.16	67
50%	4	205	50	188	50	0.1	53	0.12	50
30%	1	143	35	112	30	0.053	28	0.07	29
Endurance									
1	0.5	112	27	110	29	0.066	35	0.039	16
2	0.5	127	31	110	29	0.065	34	0.044	18
3	0.5	114	28	110	29	0.06	32	0.042	18
4	1	127	31	109	29	0.069	36	0.04	17
5	1								
6	1	152	37	111	29	0.067	35	0.042	18
7	1	135	33	115	30	0.067	35	0.042	18
8	1.5	117	29	109	29	0.069	36	0.04	17
9	1.5	101	25	112	30	0.067	35	0.04	17
10	1.5								
11	1.5	117	29	112	30	0.064	34	0.04	17
12	1.5	131	32	111	29	0.069	36	0.043	18
13	2	125	30	112	30	0.072	38	0.039	16
14	2								
15	2								
16	2	113	28	110	29	0.066	35	0.04	17
17	2	128	31	112	30	0.075	39	0.043	18
18	2	120	29	111	29	0.074	39	0.04	17
19	2	117	29	113	30	0.076	40	0.039	16
20	2.5								
21	2.5	120	29	111	29	0.071	37	0.038	16
22	2.5	112	27	112	30	0.075	39	0.04	17
23	2.5	111	27	110	29	0.069	36	0.039	16
24	2.5	106	26	110	29	0.074	39	0.039	16
25	3								
26	3	115	28	112	30	0.066	35	0.04	17
27	3	126	31	110	29	0.074	39	0.04	17
28	3	131	32	110	29	0.08	42	0.039	16
29	3	129	31	110	29	0.065	34	0.039	16
30	3.5								
31	3.5	123	30	112	30	0.065	34	0.04	17
32	3.5	126	31	111	29	0.066	35	0.039	16
33	4	132	32	111	29	0.073	38	0.04	17
34	4	128	31	110	29	0.078	41	0.046	19
35	4								
36	4	143	35	109	29	0.077	41	0.047	20
37	4.5	130	32	110	29	0.085	45	0.047	20
38	4.5	130	32	112	30	0.088	46	0.045	19
39	4.5	123	30	111	29	0.082	43	0.046	19
40	5								
41	5	154	38	108	29	0.09	47	0.064	27
42	5	144	35	110	29	0.084	44	0.05	21
43	5	135	33	112	30	0.092	48	0.055	23
44	5.5	133	32	111	29	0.094	49	0.051	21
45	5.5								
Recovery									
1		136	33	110	29	0.088	46	0.052	22
3		134	33	111	29	0.071	37	0.055	23
5		146	36	110	29	0.079	42	0.055	23
10		116	28	111	29	0.068	36	0.04	17

Control 1

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	213	100	180	100	0.21	100	0.23	100
70%	5	75	35	126	70	0.08	38	0.14	61
50%	3	67	31	90	50	0.07	33	0.07	30
30%	1	42	20	54	30	0.04	19	0.054	23
Endurance									
1	0.5	38	18	56	31	0.036	17	0.068	30
2	0.5	34	16	58	32	0.028	13	0.06	26
3	1	34	16	58	32	0.038	18	0.066	29
4	1	38	18	55	31	0.029	14	0.065	28
5	1								
6	1.5	34	16	55	31	0.034	16	0.05	22
7	2	41	19	53	29	0.035	17	0.06	26
8	2	39	18	55	31	0.035	17	0.052	23
9	2	32	15	54	30	0.038	18	0.065	28
10	2								
11	2	54	25	54	30	0.029	14	0.066	29
12	2	41	19	55	31	0.03	14	0.06	26
13	3	41	19	52	29	0.031	15	0.06	26
14	3	38	18	54	30	0.032	15	0.058	25
15	3								
16	3	41	19	52	29	0.029	14	0.063	27
17	3	46	22	54	30	0.035	17	0.067	29
18	3	44	21	55	31	0.034	16	0.065	28
19	3	57	27	55	31	0.042	20	0.067	29
20	3.5								
21	4	55	26	55	31	0.052	25	0.073	32
22	4	53	25	54	30	0.042	20	0.06	26
23	4	49	23	55	31	0.052	25	0.06	26
24	4	51	24	56	31	0.05	24	0.063	27
25	5								
26	5	64	30	54	30	0.06	29	0.055	24
27	5	55	26	55	31	0.06	29	0.06	26
28	5	54	25	56	31	0.08	38	0.06	26
29	5	55	26	54	30	0.067	32	0.062	27
30	5								
31	5.5	40	19	55	31	0.068	32	0.062	27
32	6	59	28	52	29	0.06	29	0.06	26
33	6	62	29	54	30	0.054	26	0.061	27
34	6.5	66	31	53	29	0.051	24	0.06	26
35	6.5								
36	7	76	36	53	29	0.055	26	0.058	25
37	7	78	37	56	31	0.075	36	0.069	30
38	7	66	31	55	31	0.078	37	0.068	30
39	7.5	69	32	56	31	0.087	41	0.067	29
40	7.5								
41	8	85	40	54	30	0.091	43	0.085	37
42	8	90	42	53	29	0.098	47	0.071	31
43	8	77	36	55	31	0.095	45	0.079	34
44	8	94	44	55	31	0.099	47	0.079	34
45	8.5								
Recovery									
1		76	36	51	28	0.073	35	0.068	30
3		73	34	53	29	0.05	24	0.06	26
5		70	33	53	29	0.044	21	0.069	30
10		58	27	55	31	0.035	17	0.065	28

Control 2

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	250	100	271	100	0.27	100	0.28	100
70%	7	140	56	189	70	0.16	59	0.19	68
50%	3	128	51	135	50	0.071	26	0.13	46
30%	1	71	28	81	30	0.045	17	0.068	24
Endurance									
1	1	49	20	82	30	0.038	14	0.069	25
2	1	64	26	93	34	0.042	16	0.07	25
3	1	52	21	85	31	0.032	12	0.072	26
4	1	65	26	80	30	0.028	10	0.07	25
5	1								
6	2	63	25	82	30	0.03	11	0.085	30
7	2	35	14	82	30	0.032	12	0.066	24
8	2	66	26	81	30	0.036	13	0.08	29
9	2	93	37	80	30	0.036	13	0.075	27
10	2								
11	2	59	24	83	31	0.041	15	0.066	24
12	2	54	22	79	29	0.05	19	0.077	28
13	3	67	27	75	28	0.026	10	0.068	24
14	3	68	27	82	30	0.05	19	0.062	22
15	3								
16	4	50	20	77	28	0.035	13	0.071	25
17	4	64	26	77	28	0.028	10	0.061	22
18	4	72	29	81	30	0.036	13	0.088	31
19	4	75	30	79	29	0.041	15	0.084	30
20	4								
21	4	88	35	91	34	0.038	14	0.073	26
22	5	81	32	81	30	0.04	15	0.06	21
23	5	80	32	80	30	0.042	16	0.066	24
24	5	42	17	88	32	0.034	13	0.07	25
25	6								
26	6	53	21	82	30	0.031	11	0.06	21
27	6	68	27	81	30	0.035	13	0.065	23
28	7	70	28	81	30	0.032	12	0.061	22
29	7	60	24	76	28	0.027	10	0.067	24
30	7								
31	7	70	28	78	29	0.031	11	0.066	24
32	8	61	24	81	30	0.027	10	0.084	30
33	8	74	30	74	27	0.04	15	0.094	34
34	8	51	20	77	28	0.034	13	0.068	24
35	8								
36	9	98	39	76	28	0.064	24	0.065	23
37	9	102	41	83	31	0.053	20	0.08	29
38	9	87	35	83	31	0.041	15	0.07	25
39	9	84	34	87	32	0.066	24	0.097	35
40	9								
41	10	92	37	80	30	0.065	24	0.088	31
42	10	133	53	81	30	0.1	37	0.088	31
43	11	89	36	79	29	0.062	23	0.12	43
44	11	134	54	82	30	0.11	41	0.1	36
45	11								
Recovery									
1		96	38	88	32	0.051	19	0.093	33
3		88	35	80	30	0.032	12	0.09	32
5		59	24	82	30	0.03	11	0.075	27
10		53	21	77	28	0.03	11	0.092	33

Control 3

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	367	100	324	100	0.34	100	0.31	100
70%	6	144	39	228	70	0.167	49	0.152	49
50%	3	132	36	163	50	0.14	41	0.09	29
30%	1	91	25	97	30	0.09	26	0.047	15
Endurance									
1	1	56	15	96	30	0.048	14	0.035	11
2	1	70	19	98	30	0.05	15	0.034	11
3	1.5	61	17	97	30	0.048	14	0.036	12
4	2	66	18	96	30	0.05	15	0.038	12
5	2								
6	2	87	24	99	31	0.055	16	0.035	11
7	2	78	21	98	30	0.056	16	0.036	12
8	2	66	18	98	30	0.049	14	0.035	11
9	2	73	20	97	30	0.05	15	0.038	12
10	3								
11	3	85	23	97	30	0.052	15	0.039	13
12	3	82	22	98	30	0.049	14	0.039	13
13	3	70	19	96	30	0.047	14	0.037	12
14	3	84	23	97	30	0.047	14	0.036	12
15	3.5								
16	3.5								
17	4	82	22	97	30	0.05	15	0.037	12
18	4	76	21	95	29	0.05	15	0.038	12
19	4	84	23	98	30	0.048	14	0.043	14
20	4.5								
21	5	74	20	96	30	0.048	14	0.039	13
22	5	72	20	97	30	0.046	14	0.045	15
23	5	80	22	95	29	0.048	14	0.042	14
24	5	85	23	96	30	0.05	15	0.046	15
25	5.5								
26	5.5	70	19	96	30	0.048	14	0.044	14
27	6	74	20	97	30	0.047	14	0.039	13
28	6	81	22	95	29	0.046	14	0.046	15
29	6	74	20	96	30	0.048	14	0.04	13
30	6.5								
31	6.5	70	19	96	30	0.049	14	0.041	13
32	6.5	90	25	97	30	0.05	15	0.049	16
33	7	99	27	96	30	0.057	17	0.041	13
34	7	91	25	97	30	0.049	14	0.049	16
35	7								
36	7	89	24	97	30	0.047	14	0.047	15
37	7	92	25	98	30	0.049	14	0.051	16
38	7	86	23	98	30	0.049	14	0.05	16
39	7	70	19	97	30	0.046	14	0.041	13
40	7								
41	7	90	25	96	30	0.051	15	0.043	14
42	7.5	105	29	97	30	0.051	15	0.054	17
43	7.5	87	24	96	30	0.049	14	0.048	15
44	8	98	27	95	29	0.053	16	0.048	15
45	8								
Recovery									
1		118	32	93	29	0.061	18	0.047	15
3		166	45	93	29	0.082	24	0.044	14
5		110	30	96	30	0.067	20	0.04	13
10		129	35	96	30	0.082	24	0.048	15

Control 4

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	334	100	290	100	0.078	100	0.084	100
70%	3	178	53	203	70	0.058	74	0.071	85
50%	2	85	25	145	50	0.05	64	0.047	56
30%	1	79	24	87	30	0.039	50	0.026	31
Endurance									
1	1	65	19	85	29	0.029	37	0.043	51
2	2	61	18	87	30	0.03	38	0.036	43
3	2	84	25	85	29	0.024	31	0.037	44
4	2	80	24	86	30	0.028	36	0.036	43
5	2								
6	3	59	18	85	29	0.027	35	0.039	46
7	3	62	19	84	29	0.026	33	0.042	50
8	3	57	17	88	30	0.027	35	0.036	43
9	3	52	16	87	30	0.025	32	0.037	44
10	3								
11	3	52	16	83	29	0.029	37	0.039	46
12	3	48	14	87	30	0.032	41	0.037	44
13	3	51	15	86	30	0.034	44	0.037	44
14	3	53	16	88	30	0.034	44	0.042	50
15	3								
16	3	52	16	83	29	0.024	31	0.037	44
17	3	60	18	87	30	0.025	32	0.037	44
18	3	54	16	86	30	0.028	36	0.038	45
19	3	82	25	88	30	0.03	38	0.037	44
20	3								
21	3	58	17	87	30	0.025	32	0.039	46
22	3	59	18	87	30	0.026	33	0.043	51
23	3	60	18	88	30	0.032	41	0.039	46
24	3	55	16	86	30	0.03	38	0.041	49
25	3								
26	3	57	17	84	29	0.027	35	0.041	49
27	3	58	17	82	28	0.029	37	0.046	55
28	3	61	18	88	30	0.03	38	0.038	45
29	3	65	19	86	30	0.033	42	0.04	48
30	3								
31	3	70	21	84	29	0.028	36	0.038	45
32	4	87	26	82	28	0.026	33	0.041	49
33	4	74	22	88	30	0.03	38	0.042	50
34	4	70	21	86	30	0.029	37	0.04	48
35	4								
36	4	76	23	85	29	0.028	36	0.041	49
37	4	92	28	86	30	0.029	37	0.042	50
38	4	76	23	87	30	0.038	49	0.056	67
39	4	70	21	86	30	0.036	46	0.045	54
40	4								
41	4	82	25	84	29	0.038	49	0.041	49
42	4	89	27	82	28	0.045	58	0.058	69
43	5	90	27	88	30	0.031	40	0.042	50
44	5	102	31	87	30	0.038	49	0.041	49
45	5								
Recovery									
1		151	45	86	30	0.039	50	0.039	46
3		154	46	85	29	0.033	42	0.038	45
5		167	50	87	30	0.044	56	0.045	54
10		143	43	88	30	0.048	62	0.048	57

Control 5

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	334	100	306	100	0.2	100	0.19	100
70%	5	164	49	214	70	0.19	95	0.11	58
50%	3	112	34	153	50	0.045	23	0.07	37
30%	1	64	19	91	30	0.023	12	0.04	21
Endurance									
1	1	67	20	91	30	0.02	10	0.044	23
2	1	40	12	90	29	0.022	11	0.047	25
3	2	76	23	89	29	0.019	10	0.042	22
4	2	75	22	93	30	0.021	11	0.05	26
5	2								
6	2	76	23	90	29	0.02	10	0.045	24
7	3	87	26	92	30	0.019	10	0.047	25
8	3	78	23	90	29	0.019	10	0.049	26
9	3	98	29	91	30	0.023	12	0.055	29
10	4								
11	4	96	29	92	30	0.02	10	0.055	29
12	4	82	25	88	29	0.019	10	0.058	31
13	4	82	25	91	30	0.022	11	0.055	29
14	4	91	27	90	29	0.021	11	0.058	31
15	5								
16	5	103	31	95	31	0.02	10	0.057	30
17	5	101	30	92	30	0.021	11	0.056	29
18	5	83	25	91	30	0.024	12	0.052	27
19	5	102	31	90	29	0.02	10	0.058	31
20	6								
21	6	75	22	92	30	0.023	12	0.058	31
22	6	75	22	91	30	0.024	12	0.062	33
23	6	81	24	90	29	0.021	11	0.065	34
24	6	80	24	90	29	0.019	10	0.06	32
25	6								
26	7	96	29	91	30	0.023	12	0.05	26
27	7	96	29	90	29	0.022	11	0.053	28
28	7	81	24	89	29	0.024	12	0.06	32
29	7	80	24	91	30	0.025	13	0.057	30
30	7								
31	7	94	28	93	30	0.022	11	0.065	34
32	7	99	30	92	30	0.023	12	0.063	33
33	7	106	32	91	30	0.029	15	0.065	34
34	7	73	22	91	30	0.023	12	0.059	31
35	8								
36	8	46	14	89	29	0.021	11	0.06	32
37	8	61	18	88	29	0.024	12	0.067	35
38	8	97	29	90	29	0.031	16	0.059	31
39	8	81	24	90	29	0.045	23	0.065	34
40	8								
41	8	88	26	89	29	0.03	15	0.062	33
42	8	107	32	88	29	0.031	16	0.067	35
43	8	93	28	91	30	0.042	21	0.063	33
44	8	93	28	92	30	0.03	15	0.062	33
45	8								
Recovery									
1		102	31	91	30	0.019	10	0.051	27
3		87	26	89	29	0.015	8	0.056	29
5		105	31	90	29	0.021	11	0.065	34
10		124	37	91	30	0.019	10	0.067	35

Control 6

Time	RPE	Force Matching	%	Force Reference	%	EMG Matching	%	EMG Reference	%
Baseline									
MVC	11	383	100	362	100	0.3	100	0.3	100
70%	5	144	38	253	70	0.24	80	0.3	100
50%	2	149	39	181	50	0.13	43	0.1	33
30%	0.5	64	17	108	30	0.047	16	0.07	23
Endurance									
1	0.5	56	15	106	29	0.026	9	0.055	18
2	0.5	54	14	105	29	0.022	7	0.059	20
3	1	52	14	105	29	0.028	9	0.056	19
4	1	67	17	106	29	0.029	10	0.057	19
5	2								
6	2	81	21	108	30	0.031	10	0.058	19
7	2	69	18	106	29	0.032	11	0.055	18
8	3	82	21	103	28	0.048	16	0.057	19
9	3	57	15	108	30	0.029	10	0.054	18
10	3								
11	3	64	17	108	30	0.03	10	0.053	18
12	3.5	60	16	106	29	0.036	12	0.054	18
13	3.5		0		0		0		0
14	4	61	16	106	29	0.032	11	0.056	19
15	4								
16	4	52	14	108	30	0.033	11	0.052	17
17	4	48	13	105	29	0.035	12	0.05	17
18	5	58	15	103	28	0.031	10	0.051	17
19	5	59	15	105	29	0.031	10	0.051	17
20	5								
21	5	58	15	105	29	0.029	10	0.05	17
22	5	59	15	106	29	0.031	10	0.05	17
23	5	71	19	108	30	0.034	11	0.055	18
24	5.5	58	15	108	30	0.034	11	0.052	17
25	6								
26	6	63	16	106	29	0.038	13	0.054	18
27	6	58	15	103	28	0.038	13	0.052	17
28	6	54	14	107	29	0.032	11	0.055	18
29	6	54	14	104	29	0.03	10	0.06	20
30	6								
31	6.5	58	15	107	29	0.036	12	0.052	17
32	6.5	42	11	108	30	0.03	10	0.053	18
33	6.5	55	14	106	29	0.034	11	0.053	18
34	7	55	14	107	29	0.038	13	0.054	18
35	7								
36	7	81	21	107	29	0.044	15	0.057	19
37	7	61	16	108	30	0.038	13	0.062	21
38	7	65	17	108	30	0.044	15	0.07	23
39	7	69	18	107	29	0.05	17	0.075	25
40	7								
41	8	53	14	106	29	0.058	19	0.068	23
42	8	49	13	104	29	0.068	23	0.072	24
43	8	64	17	104	29	0.058	19	0.07	23
44	8	64	17	105	29	0.063	21	0.069	23
45	8								
Recovery									
1		45	12	105	29	Invalid		0.07	23
3		64	17	106	29			0.068	23
5		63	16	108	29			0.068	23
10		59	15	107	29			0.065	22

Baseline Measurements

Force (newtons)

MVC

	Ref Arm		Matching Arm	
	CFS	Control	CFS	Control
Subject 1	234	180	262	213
Subject 2	143	271	146	250
Subject 3	481	324	498	367
Subject 4	237	290	242	334
Subject 5	348	303	366	334
Subject 6	378	362	410	383
Mean	303.5	288.83	320.67	313.50
St Dev	121.70	61.72	127.77	67.33
SEM	49.69	25.20	52.17	27.49

EMG (Volts)

MVC

	Ref Arm		Matching Arm	
	CFS	Control	CFS	Control
Subject 1	0.191	0.23	0.2	0.21
Subject 2	0.067	0.28	0.065	0.27
Subject 3	0.32	0.31	0.38	0.34
Subject 4	0.07	0.084	0.142	0.078
Subject 5	0.188	0.19	0.09	0.2
Subject 6	0.24	0.3	0.19	0.3
Mean	0.18	0.23	0.18	0.23
St Dev	0.10	0.09	0.11	0.09
SEM	0.04	0.03	0.05	0.04

Matching Force (Normalised)

	70% Match		50% Match		30% Match	
	CFS	Control	CFS	Control	CFS	Control
Subject 1	35	35	29	31	16	20
Subject 2	66	56	49	51	40	28
Subject 3	58	39	52	36	34	25
Subject 4	69	53	36	25	22	24
Subject 5	27	49	32	34	23	19
Subject 6	52	38	50	39	35	17
Mean	51.17	45.00	41.33	36.00	28.33	22.17
St Dev	16.92	8.79	10.15	8.76	9.31	4.17
SEM	6.91	3.59	4.15	3.58	3.80	1.70

Matching EMG (Normalised)

	70% Match		50% Match		30% Match	
	CFS	Control	CFS	Control	CFS	Control
Subject 1	35	38	25	33	25	19
Subject 2	60	59	49	26	32	17
Subject 3	61	49	37	41	17	26
Subject 4	63	74	42	64	23	50
Subject 5	50	95	56	23	38	12
Subject 6	63	80	53	43	28	16
Mean	55.33	65.83	43.67	38.33	27.17	23.33
St Dev	10.11	19.25	10.51	13.56	6.67	12.64
SEM	4.13	7.86	4.29	5.54	2.72	5.16

RPE

	MVC		70%		50%		30%	
	CFS	Control	CFS	Control	CFS	Control	CFS	Control
Subject 1	11	11	8	5	7	3	3	1
Subject 2	11	11	8	7	6	3	3	1
Subject 3	11	11	7	6	5	3	3	1
Subject 4	11	11	8	3	6	2	4	1
Subject 5	11	11	8	5	7	3	5	1
Subject 6	11	11	6	5	4	2	1	0.5
Mean	11.00	11.00	7.50	5.17	5.83	2.67	3.17	0.92
Stdev	0.00	0.00	0.84	1.33	1.17	0.52	1.33	0.20
SEM	0	0.00	0.34	0.54	0.48	0.21	0.54	0.08

Appendix

MVC force & EMG for Fatiguing Task

Endurance MVC - Force for Fatiguing Task (Normalised)

CFS

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	St. Dev	SEM
Endurance									
MVC	100	100	100	100	100	100	100	0	0
5	90	92	81	82	92	93	88	5	2
10	94	88	89	78	79	95	87	7	3
15	92	92	77	81	84	95	87	7	3
20	94	84	84	70	82	90	84	8	3
25	85	78	78	57	84	81	77	10	4
30	85	80	83	62	78	90	80	9	4
35	61	77	70	70	68	88	72	9	4
40	65	62	58	76	55	83	67	11	4
45	86	53	46	76	53	84	66	18	7
Recovery									
1	77	68	71	74	62	84	73	7	3
3	77	97	83	73	69	96	82	12	5
5	71	103	93	103		99	94	14	6
10	100	108	90	91	74	104	95	12	5

Endurance MVC - Force for Fatiguing Task (Normalised)

Controls

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	St Dev	SEM
Endurance									
MVC	100	100	100	100	100	100	100	0	0
5	88	85	92	87	81	89	87	4	1
10	87	79	93	99	65	80	82	10	4
15	81	82	87	88	61	75	79	10	4
20	74	74	86	81	44	86	74	16	6
25	71	69	81	84	80	75	77	6	2
30	66	68	87	78	63	69	72	9	4
35	66	65	86	77	63	73	72	9	4
40	58	58	86	69	60	58	65	11	5
45	68	52	71	66	64	53	62	8	3
Recovery									
1	75	62	72	74	71	84	73	7	3
3	78	67	65	77	72	85	74	8	3
5	85	65	81	80	80	89	80	8	3
10	83	74	78	87	85	97	84	8	3

Appendix

MVC rmsEMG for Fatiguing Task (Normalised)

CFS

	Subject 1	Subject 2	Subjec+D'	Subject 4	Subject 5	Subject 6	Mean	St. Dev	SEM
Endurance									
MVC	100	100	100	100	100	100	100	0	
5	105	54	66	71		79	75	19	9
10	68	48	59	77		75	65	12	5
15	68	51	41	70		83	63	17	7
20	58	46	50	66		79	60	13	6
25	53	48	53	76		71	60	12	6
30	53	48	47	61		75	57	12	5
35	37	51	47	81		75	58	19	8
40	47	54	41	76		67	57	14	6
45	63	66	38	76		71	63	15	7
Recovery									
1	32	48	53	74		71	56	17	8
3	42	63	69	66		67	61	11	5
5	32	69	75	79		79	67	20	9
10	53	72	69	84		71	70	11	5

MVC rmsEMG for Fatiguing Task (Normalised)

Controls

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	St. Dev	SEM
Endurance									
MVC	100	100	100	100	100	100	100	0	
5	65	93	97	143	89	63	92	29	13
10	61	61	65	119	58	40	67	27	12
15	61	50	74	113	68	50	69	23	10
20	48	50	74	107	42	43	61	26	11
25	57	46	58	131	53	37	64	34	15
30	57	39	58	94	47	47	57	19	9
35	57	36	61	101	53	43	59	23	10
40	48	36	71	151	63	37	68	43	19
45	57	46	68	145	79	30	71	40	18
Recovery									
1	57	54	39	79	63	43	56	14	6
3	48	64	48	81	79	43	61	17	7
5	70	64	68	111	89	57	77	20	9
10	61	71	84	104	95	60	79	18	8

RPE

Control Endurance	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	St Dev	SEM
1	0.5	1	1	1	1	0.5	0.83	0.26	0.11
2	0.5	1	1	1	2	0.5	1.00	0.55	0.22
3	1	1	1.5	2	2	1	1.42	0.49	0.20
4	1	1	2	2	2	1	1.50	0.55	0.22
5	1	1	2	2	2	2	1.67	0.52	0.21
6	1.5	2	2	2	3	2	2.08	0.49	0.20
7	2	2	2	3	3	2	2.33	0.52	0.21
8	2	2	2	3	3	3	2.50	0.55	0.22
9	2	2	2	3	3	3	2.50	0.55	0.22
10	2	2	3	4	3	3	2.83	0.75	0.31
11	2	2	3	4	3	3	2.83	0.75	0.31
12	2	2	3	4	3	3.5	2.92	0.80	0.33
13	3	3	3	4	3	3.5	3.25	0.42	0.17
14	3	3	3	4	3	4	3.33	0.52	0.21
15	3	3	3.5	5	3	4	3.58	0.80	0.33
16	3	4	3.5	5	3	4	3.75	0.76	0.31
17	3	4	4	5	3	4	3.83	0.75	0.31
18	3	4	4	5	3	5	4.00	0.89	0.37
19	3	4	4	5	3	5	4.00	0.89	0.37
20	3.5	4	4.5	6	3	5	4.33	1.08	0.44
21	4	4	5	6	3	5	4.50	1.05	0.43
22	4	5	5	6	3	5	4.67	1.03	0.42
23	4	5	5	6	3	5	4.67	1.03	0.42
24	4	5	5	6	3	5.5	4.75	1.08	0.44
25	5	6	5.5	6	3	6	5.25	1.17	0.48
26	5	6	5.5	7	3	6	5.42	1.36	0.55
27	5	6	6	7	3	6	5.50	1.38	0.56
28	5	7	6	7	3	6	5.67	1.51	0.61
29	5	7	6	7	3	6	5.67	1.51	0.61
30	5	7	6.5	7	3	6	5.75	1.54	0.63
31	5.5	7	6.5	7	3	6.5	5.92	1.53	0.62
32	6	8	6.5	7	4	6.5	6.33	1.33	0.54
33	6	8	7	7	4	6.5	6.42	1.36	0.55
34	6.5	8	7	7	4	7	6.58	1.36	0.55
35	6.5	8	7	8	4	7	6.75	1.47	0.60
36	7	9	7	8	4	7	7.00	1.67	0.68
37	7	9	7	8	4	7	7.00	1.67	0.68
38	7	9	7	8	4	7	7.00	1.67	0.68
39	7.5	9	7	8	4	7	7.08	1.69	0.69
40	7.5	9	7	8	4	7	7.08	1.69	0.69
41	8	10	7	8	4	8	7.50	1.97	0.81
42	8	10	7.5	8	4	8	7.58	1.96	0.80
43	8	11	7.5	8	5	8	7.92	1.91	0.78
44	8	11	8	8	5	8	8.00	1.90	0.77
45	8.5	11	8	8	5	8	8.08	1.91	0.78

RPE

CFS	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	ST Dev	SEM
Endurance									
1	3	2	3	4	3	0.5	2.58	1.20	0.49
2	3	2	3	4	3	0.5	2.58	1.20	0.49
3	4	2	3	5	4	0.5	3.08	1.63	0.66
4	4	2	5	5	4	1	3.50	1.64	0.67
5	4	3	5	6	5	1	4.00	1.79	0.73
6	4	3	5	6	5	1	4.00	1.79	0.73
7	5	3	5	6	5	1	4.17	1.83	0.75
8	5	3	5	7	4	1.5	4.25	1.89	0.77
9	5	3	5	7	4	1.5	4.25	1.89	0.77
10	6	3	6	7	5	1.5	4.75	2.09	0.85
11	6	3	6	7	5	1.5	4.75	2.09	0.85
12	7	4	6	7	5	1.5	5.08	2.11	0.86
13	6	4	7	7	5	2	5.17	1.94	0.79
14	6	4	8	7	5	2	5.33	2.16	0.88
15	7	4	8	7	5	2	5.50	2.26	0.92
16	7	4	8	7	5	2	5.50	2.26	0.92
17	7	5	8	7	5	2	5.67	2.16	0.88
18	7	5	8	7	6	2	5.83	2.14	0.87
19	7	5	9	8	6	2	6.17	2.48	1.01
20	8	5	9	8	6	2.5	6.42	2.42	0.99
21	8	6	9	8	6	2.5	6.58	2.33	0.95
22	8	6	10	8	6	2.5	6.75	2.56	1.05
23	8	6	10	8	6	2.5	6.75	2.56	1.05
24	8	7	10	8	6	2.5	6.92	2.54	1.04
25	8	7	10	9	7	3	7.33	2.42	0.99
26	8	7	9	8	7	3	7.00	2.10	0.86
27	8	7	9	9	7	3	7.17	2.23	0.91
28	8	8	9	9	7	3	7.33	2.25	0.92
29	8.5	8	9	9	7	3	7.42	2.29	0.93
30	8.5	8	9	10	8	3.5	7.83	2.25	0.92
31	8.5	8	10	10	8	3.5	8.00	2.39	0.97
32	8.5	8	10	10	8	3.5	8.00	2.39	0.97
33	8.5	8	10	9	8	4	7.92	2.06	0.84
34	8.5	8	10	9	8	4	7.92	2.06	0.84
35	9	9	10	9	9	4	8.33	2.16	0.88
36	9	9	10	9	9	4	8.33	2.16	0.88
37	9	9	10	10	9	4.5	8.58	2.06	0.84
38	9	9	10	10	9	4.5	8.58	2.06	0.84
39	9	10	11	10	10	4.5	9.08	2.33	0.95
40	10	10	11	11	10	5	9.50	2.26	0.92
41	10	10	11	11	10	5	9.50	2.26	0.92
42	10	10	11	11	10	5	9.50	2.26	0.92
43	11	10	11	11	10	5	9.67	2.34	0.95
44	11	10	11	11	10	5.5	9.75	2.14	0.87
45	11	10	11	11	10	5.5	9.75	2.14	0.87

Control

Reference EMG - Normalised

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	St. Dev	SEM
Endurance									
1	30	25	11	51	23	18	26	14	6
2	26	25	11	43	25	20	25	10	4
3	29	26	12	44	22	19	25	11	4
4	28	25	12	43	26	19	26	10	4
Average	**28**	**25**	**12**	**45**	**24**	**19**	**26**	**11**	**5**
6	22	30	11	46	24	19	25	12	5
7	26	24	12	50	25	18	26	13	5
8	23	29	11	43	26	19	25	11	4
9	28	27	12	44	29	18	26	11	4
Average	**25**	**27**	**12**	**46**	**26**	**19**	**26**	**11**	**5**
11	29	24	13	46	29	18	26	12	5
12	26	28	13	44	31	18	26	11	4
13	26	24	12	44	29		27	12	5
14	25	22	12	50	31	19	26	13	5
Average	**27**	**24**	**12**	**46**	**30**	**18**	**27**	**12**	**5**
16	27	25		44	30	17	29	10	4
17	29	22	12	44	29	17	26	11	5
18	28	31	12	45	27	17	27	12	5
19	29	30	14	44	31	17	27	11	4
Average	**28**	**27**	**13**	**44**	**29**	**17**	**27**	**11**	**4**
21	32	26	13	46	31	17	27	12	5
22	26	21	15	51	33	17	27	14	6
23	26	24	14	46	34	18	27	12	5
24	27	25	15	49	32	17	27	12	5
Average	**28**	**24**	**14**	**48**	**32**	**17**	**27**	**12**	**5**
26	24	21	14	49	26	18	25	12	5
27	26	23	13	55	28	17	27	15	6
28	26	22	15	45	32	18	26	11	4
29	27	24	13	48	30	20	27	12	5
Average	**26**	**23**	**14**	**49**	**29**	**18**	**26**	**12**	**5**
31	27	24	13	45	34	17	27	12	5
32	26	30	16	49	33	18	29	12	5
33	27	34	13	50	34	18	29	13	5
34	26	24	16	48	31	18	27	11	5
Average	**26**	**28**	**15**	**48**	**33**	**18**	**28**	**12**	**5**
36	25	23	15	49	32	19	27	12	5
37	30	29	16	50	35	21	30	12	5
38	30	25	16	67	31	23	32	18	7
39	29	35	13	54	34	25	32	13	5
Average	**28**	**28**	**15**	**55**	**33**	**22**	**30**	**13**	**6**
41	37	31	14	49	33	23	31	12	5
42	31	31	17	69	35	24	35	18	7
43	34	43	15	50	33	23	33	13	5
44	34	36	15	49	33	23	32	11	5
Average	**34**	**35**	**16**	**54**	**33**	**23**	**33**	**13**	**5**
Recovery									
1	30	33	15	46	27	23	29	10	4
3	26	32	14	45	29	23	28	10	4
5	30	27	13	54	34	23	30	14	6
10	28	33	15	57	35	22	32	14	6

CFS

Reference EMG Normalised

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	St.dev	SEM
Endurance									
1	20	37	16	49	15	16	25	14	6
2	25	36	16	53	17	18	28	14	6
3	23	39	16	53	9	18	26	16	7
4	17	34	14	56	8	17	24	18	7
Average	**21**	**37**	**15**	**53**	**12**	**17**	**26**	**16**	**6**
6	17	37	14	53	16	18	26	16	6
7	20	37	14	53	14	18	26	16	6
8	17	37	14	53		17	28	17	7
9	17	34	15	56	12	17	25	17	7
Average	**18**	**37**	**14**	**54**	**14**	**17**	**26**	**16**	**7**
11	22	34	16	56	18	17	27	16	6
12	23	39	14	53		18	29	16	7
13	26	37	14	54		16	30	17	7
14	22	37	14	60			33	20	8
Average	**23**	**37**	**15**	**56**	**18**	**17**	**30**	**16**	**7**
16	17	33	14	56		17	27	18	7
17	16	33	15	50	14	18	24	14	6
18	20	34	14	53		17	28	16	7
19	24	37	14	56	14	16	27	17	7
Average	**19**	**34**	**14**	**54**	**14**	**17**	**27**	**16**	**6**
21	24	34	15	54	18	16	27	15	6
22	20	34	15	56		17	28	17	7
23	20	36	13	56		16	28	18	7
24	21	36	15	57	16	16	27	17	7
Average	**21**	**35**	**14**	**56**	**16**	**16**	**28**	**16**	**7**
26	20	33	15	57	14	17	26	17	7
27	22	33	15	56	11	17	25	17	7
28	26	39	15	57		16	31	18	7
29	21	40	14	57	17	16	28	17	7
Average	**22**	**36**	**15**	**57**	**14**	**16**	**27**	**17**	**7**
31	19	42	15	56		17	30	18	7
32	21	39	15	57	10	16	26	18	7
33	21	37	14	60	19	17	28	18	7
34	20	39	18	60	19	19	29	17	7
Average	**20**	**39**	**16**	**58**	**16**	**17**	**28**	**17**	**7**
36	23	45	16	64	13	20	30	20	8
37	30	52	16	63	27	20	35	19	8
38	20	54	18	64	20	19	33	21	8
39	25	51	19	67	16	19	33	21	9
Average	**25**	**50**	**18**	**65**	**19**	**19**	**33**	**20**	**8**
41	26	52	19	63		27	37	19	8
42	31	48	21	67		21	37	20	8
43	29	49	23	64		23	38	18	7
44	35	55	28	60		21	40	17	7
Average	**30**	**51**	**23**	**64**		**23**	**38**	**18**	**8**
Recovery									
1	17	37	28	71			39	23	10
3	16	37	24	77			39	27	11
5	18	39	23	77			39	27	11
10	17	40	23	76			39	27	11

Control

Matching EMG - Normalised

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	St.dev	SEM
Endurance									
1	17	14	14	37	10	9	17	10	4
2	13	16	15	38	11	7	17	11	5
3	18	12	14	31	10	9	16	8	3
4	14	10	15	36	11	10	16	10	4
Average	**16**	**13**	**14**	**36**	**10**	**9**	**16**	**10**	**4**
6	16	11	16	35	10	10	16	9	4
7	17	12	16	33	10	11	16	9	4
8	17	13	14	35	10	16	17	9	4
9	18	13	15	32	12	10	17	8	3
Average	**17**	**12**	**15**	**34**	**10**	**12**	**17**	**9**	**4**
11	14	15	15	37	10	10	17	10	4
12	14	19	14	41	10	12	18	12	5
13	15	10	14	44	11		19	14	6
14	15	19	14	44	11	11	19	13	5
Average	**15**	**15**	**14**	**41**	**10**	**11**	**18**	**12**	**5**
16	14	13		31	10	11	16	9	3
17	17	10	15	32	11	12	16	8	3
18	16	13	15	36	12	10	17	9	4
19	20	15	14	38	10	10	18	11	4
Average	**17**	**13**	**15**	**34**	**11**	**11**	**17**	**9**	**4**
21	25	14	14	32	12	10	18	9	4
22	20	15	14	33	12	10	17	9	3
23	25	16	14	41	11	11	20	12	5
24	24	13	15	38	10	11	18	11	5
Average	**23**	**14**	**14**	**36**	**11**	**11**	**18**	**10**	**4**
26	29	11	14	35	12	13	19	10	4
27	29	13	14	37	11	13	19	11	4
28	38	12	14	38	12	11	21	14	6
29	32	10	14	42	13	10	20	14	6
Average	**32**	**12**	**14**	**38**	**12**	**12**	**20**	**12**	**5**
31	32	11	14	36	11	12	20	11	5
32	29	10	15	33	12	10	18	10	4
33	26	15	17	38	15	11	20	10	4
34	24	13	14	37	12	13	19	10	4
Average	**28**	**12**	**15**	**36**	**12**	**12**	**19**	**10**	**4**
36	26	24	14	36	11	15	21	10	4
37	36	20	14	37	12	13	22	12	5
38	37	15	14	49	16	15	24	15	6
39	41	24	14	46	23	17	27	13	5
Average	**35**	**21**	**14**	**42**	**15**	**15**	**24**	**12**	**5**
41	43	24	15	49	15	19	28	15	6
42	47	37	15	58	16	23	32	18	7
43	45	23	14	40	21	19	27	12	5
44	47	41	16	49	15	21	31	16	6
Average	**46**	**31**	**15**	**49**	**17**	**21**	**30**	**15**	**6**
Recovery									
1	35	19	18	50	10		26	16	7
3	24	12	24	42	8		22	14	6
5	21	11	20	56	11		24	19	8
10	17	11	24	62	10		25	21	9

CFS

Matching EMG Normalised

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	St. Dev	SEM
Endurance									
1	12	28	12	18	41	35	24	12	5
2	17	32	12	17	64	34	29	19	8
3	12	31	14	22	53	32	27	15	6
4	12	29	16	21	28	36	24	9	4
Average	**13**	**30**	**14**	**19**	**47**	**34**	**26**	**13**	**5**
6	13	34	15	22	28	35	24	10	4
7	17	40	16	23	23	35	26	10	4
8	18	37	18	23	20	36	25	9	4
9	15	35	16	27	21	35	25	9	4
Average	**15**	**37**	**16**	**24**	**23**	**36**	**25**	**9**	**4**
11	15	34	17	26	14	34	23	9	4
12	20	35	17	27	22	36	26	8	3
13	18	35	18	27	23	38	27	9	4
14	16	32	17	31	24		24	8	3
Average	**17**	**34**	**17**	**28**	**21**	**36**	**25**	**8**	**3**
16	18	34	16	28	31	35	27	8	3
17	20	37	18	27	43	39	31	11	4
18	20	32	15	27		39	27	10	4
19	18	38	14	27		40	28	12	5
Average	**19**	**35**	**16**	**27**	**37**	**38**	**28**	**10**	**4**
21	17	37	15	27	27	37	27	10	4
22	17	42	16	27	49	39	32	14	6
23	17	32	16	27	22	36	25	8	3
24	15	35	17	27	28	39	27	9	4
Average	**16**	**37**	**16**	**27**	**31**	**38**	**28**	**10**	**4**
26	13	38	18	27	25	35	26	10	4
27	14	34	18	28	23	39	26	9	4
28	19	35	19	31	28	42	29	9	4
29	17	35	18	28	20	34	25	8	3
Average	**16**	**36**	**18**	**29**	**24**	**38**	**27**	**9**	**4**
31	26	34	20	23	35	34	29	7	3
32	29	35	20	28	33	35	30	6	2
33	18	38	18	31	36	38	30	10	4
34	21	34	19	32	27	41	29	8	3
Average	**23**	**35**	**19**	**28**	**33**	**37**	**29**	**7**	**3**
36	22	42	29	31	35	41	33	7	3
37	18	40	24	30	33	45	32	10	4
38	22	48	25	30	36	46	34	11	4
39	21	43	24	34	27	43	32	10	4
Average	**21**	**43**	**25**	**31**	**33**	**44**	**33**	**9**	**4**
41	19	40	26	29		47	32	11	5
42	21	48	32	35		44	36	11	4
43	20	43	32	33		48	35	11	5
44	31	46	34	32		49	39	9	3
Average	**23**	**44**	**31**	**32**		**47**	**35**	**10**	**4**
Recovery									
1	26	48	23	35		46	36	11	5
3	15	42	23	37		37	31	11	5
5	15	42	19	28		42	29	12	6
10	22	43	23	22		36	29	10	4

Control

Matching Force - Normalised

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	St.Dev	SEM
Endurance									
1	18	20	15	19	20	15	18	2.35	0.96
2	16	26	19	18	12	14	17	4.76	1.94
3	16	21	17	25	23	14	19	4.46	1.82
4	18	26	18	24	22	17	21	3.67	1.50
Average	**17**	**23**	**17**	**22**	**19**	**15**	**19**	**3.07**	**1.25**
6	16	25	24	18	23	21	21	3.59	1.47
7	19	14	21	19	26	18	20	3.98	1.63
8	18	26	18	17	23	21	21	3.64	1.49
9	15	37	20	16	29	15	22	9.27	3.79
Average	**17**	**26**	**21**	**17**	**25**	**19**	**21**	**3.87**	**1.58**
11	25	24	23	16	29	17	22	5.09	2.08
12	19	22	22	14	25	16	20	3.97	1.62
13	19	27	19	15	25		21	4.63	1.89
14	18	27	23	16	27	16	21	5.35	2.18
Average	**20**	**25**	**22**	**15**	**26**	**16**	**21**	**4.47**	**1.83**
16	19	20		16	31	14	20	6.69	2.73
17	22	26	22	18	30	13	22	6.11	2.49
18	21	29	21	16	25	15	21	5.17	2.11
19	27	30	23	25	31	15	25	5.58	2.28
Average	**22**	**26**	**22**	**19**	**29**	**14**	**22**	**5.30**	**2.17**
21	26	35	20	17	22	15	23	7.18	2.93
22	25	32	20	18	22	15	22	6.08	2.48
23	23	32	22	18	24	19	23	5.08	2.08
24	24	17	23	16	24	15	20	4.18	1.71
Average	**24**	**29**	**21**	**17**	**23**	**16**	**22**	**4.80**	**1.96**
26	30	21	19	17	29	16	22	5.91	2.41
27	26	27	20	17	29	15	22	5.62	2.30
28	25	28	22	18	24	14	22	5.07	2.07
29	26	24	20	19	24	14	21	4.27	1.74
Average	**27**	**25**	**20**	**18**	**26**	**15**	**22**	**4.90**	**2.00**
31	19	28	19	21	28	15	22	5.29	2.16
32	28	24	25	26	30	11	24	6.63	2.71
33	29	30	27	22	32	14	26	6.42	2.62
34	31	20	25	21	22	14	22	5.48	2.24
Average	**27**	**26**	**24**	**23**	**28**	**14**	**23**	**5.10**	**2.08**
36	36	39	24	23	14	21	26	9.53	3.89
37	37	41	25	28	18	16	27	9.85	4.02
38	31	35	23	23	29	17	26	6.47	2.64
39	32	34	19	21	24	18	25	6.77	2.76
Average	**34**	**37**	**23**	**24**	**21**	**18**	**26**	**7.57**	**3.09**
41	40	37	25	25	26	14	28	9.44	3.86
42	42	53	29	27	32	13	33	13.87	5.66
43	36	36	24	27	28	17	28	7.36	3.01
44	44	54	27	31	28	17	33	13.31	5.43
Average	**41**	**45**	**26**	**27**	**29**	**15**	**30**	**10.80**	**4.41**
Recovery									
1	36	38	32	45	31	12	32	11.32	4.62
3	34	35	45	46	26	17	34	11.28	4.61
5	33	24	30	50	31	16	31	11.24	4.59
10	27	21	35	43	37	15	30	10.39	4.24

CFS

Matching Force Normalised

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Mean	St Dev	SEM
Endurance									
1	11	19	26	12	38	27	22	10.33	4.22
2	13	21	29	12	49	31	26	13.87	5.66
3	13	29	28	22	23	28	24	6.04	2.46
4	15	29	45	15	22	31	26	11.23	4.59
Average	**13**	**25**	**32**	**15**	**33**	**29**	**25**	**8.51**	**3.48**
6	20	36	37	15	20	37	27	10.25	4.19
7	13	40	37	17	13	33	26	12.43	5.07
8	9	35	38	17	12	29	23	12.16	4.97
9	11	32	33	24	16	25	23	8.66	3.54
Average	**13**	**35**	**36**	**18**	**15**	**31**	**25**	**10.49**	**4.28**
11	15	29	34	17	20	29	24	7.72	3.15
12	14	40	30	19	19	32	26	9.85	4.02
13	19	35	33	17	25	30	27	7.37	3.01
14	19	32	39	30	9		26	11.78	4.81
Average	**17**	**34**	**34**	**2.**	**18**	**30**	**25**	**7.98**	**3.26**
16	20	23	49	26	11	28	26	12.55	5.12
17	16	29	46	24	13	31	26	11.88	4.85
18	24	29	45	25	21	29	29	8.39	3.42
19	23	40	37	26	23	29	29	7.41	3.03
Average	**21**	**30**	**44**	**25**	**17**	**29**	**28**	**9.44**	**3.86**
21	18	28	36	25	27	29	27	5.95	2.43
22	19	36	40	23	21	27	27	8.45	3.45
23	18	30	35	28	21	27	27	5.96	2.43
24	13	29	39	29	27	26	27	8.56	3.50
Average	**17**	**31**	**37**	**26**	**24**	**27**	**27**	**6.87**	**2.81**
26	19	25	45	21	20	28	26	9.51	3.88
27	23	21	39	21	35	31	28	7.45	3.04
28	27	25	39	26	15	32	27	7.77	3.17
29	16	31	42	23	22	31	28	9.12	3.72
Average	**21**	**25**	**41**	**23**	**23**	**31**	**27**	**7.40**	**3.02**
31	13	33	41	23	21	30	27	9.86	4.03
32	20	31	50	25	25	31	30	10.48	4.28
33	17	27	50	29	18	32	29	11.97	4.89
34	18	29	46	28	23	31	29	9.71	3.96
Average	**17**	**30**	**47**	**26**	**22**	**31**	**29**	**10.29**	**4.20**
36	18	34	57	21	23	35	31	14.21	5.80
37	18	29	41	25	27	32	29	7.84	3.20
38	18	32	43	29	25	32	30	8.22	3.36
39	23	26	45	30	28	30	30	7.80	3.18
Average	**19**	**30**	**46**	**26**	**26**	**32**	**30**	**9.24**	**3.77**
41	21	34	56	22	31	38	34	12.67	5.17
42	21	39	58	36	40	35	38	11.69	4.77
43	24	45	60	32	36	33	38	12.37	5.05
44	25	46	52	30	48	32	39	11.15	4.55
Average	**23**	**41**	**56**	**30**	**39**	**35**	**37**	**11.36**	**4.64**
Recovery									
1	14	36	44	32	34	33	32	9.95	4.06
3	23	33	53	24	33	33	33	10.74	4.38
5	25	36	43	38	32	36	35	6.03	2.46
10	21	35	38	34	32	28	31	6.14	2.51

POMS

CFS T SCORES

	Tension	Depressn	Anger	Vigour	Fatigue	Confusion
Subject 1	37	41	45	52	61	59
Subject 2	37	44	47	40	64	25
Subject 3	49	60	52	30	73	57
Subject 4	49	37	56	33	67	53
Subject 5	45	39	42	49	58	37
Subject 6	63	42	41	32	64	72
Mean	46.7	43.8	47.2	39.3	64.5	50.5
SD	9.7	8.3	5.8	9.3	5.2	16.8

Control T SCORES

	Tension	Depressn	Anger	Vigour	Fatigue	Confusion
Subject 1	37	44	45	73	43	35
Subject 2	31	37	37	65	34	37
Subject 3	40	38	40	66	45	43
Subject 4	42	44	41	59	35	41
Subject 5	34	41	48	51	40	39
Subject 6	33	39	41	65	34	32
Mean	36.2	40.5	42.0	63.2	38.5	37.8
SD	4.3	3.0	3.9	7.4	4.8	4.0