The Use of Real-time Biomechanical Biofeedback to Reduce Musculoskeletal Pain and Improve Posture in Computer Users: A Matched-Pairs Randomized Trial

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Abstract

The prevalence of musculoskeletal disorders (MSD) such as neck and shoulder pain is high in computer users (Cook, Burgess-Limerick, & Chang, 2000; Griffiths, Mackey, Adamson, & Pepper, 2012; Mohammad, Hamza, & ElSais, 2015; Mohan, Justine, Jagannathan, Bt Aminudin, & Bt Johari, 2015). Although much attention is given to reducing MSD through a range of workplace programs, our efforts have met with inconsistent outcomes (Brewer et al., 2006; Kennedy et al., 2010).

Posture is considered to be an independent risk factor of modest magnitude for MSDs among computer users (Ariëns et al., 2001; Cote et al., 2009; Gerr, Marcus, & Monteilh, 2004). Given the relationship between posture and MSD, exploring new strategies to modify postural behaviour in computer users is warranted.

Biomechanical biofeedback (BBF) has demonstrated potential to retrain posture in clinical settings and within daily activities (Dean & Dean, 2006; Dworkin et al., 1985; O'Sullivan, O'Sullivan, O'Sullivan, & Dankaerts, 2013). However, BBF has not been trialled as an intervention for MSD in the workplace. The purpose of this project is to evaluate the effectiveness of real-time BBF to reduce musculoskeletal pain and retrain spinal posture in computer users.

A randomised-controlled, matched-pairs, block design was utilised. Forty-two computer users with neck, shoulder or upper back pain, working across multiple sites of a university and a large municipal organisation were recruited. They were assessed, matched to pairs and randomly allocated to one of two, three-week equivalent intensity interventions. One group was provided with a real-time, biomechanically-based postural biofeedback program utilising the BackTone™ biofeedback device, according to the device instructions. The other group received a workplace-based postural education program, involving education, practical static and dynamic postural training and development of client-centred, individually-designed reminder strategies to help participants implement their target posture. Both groups received two, 45-minute consultations by an occupational therapist. The primary researcher administered the biofeedback intervention; a qualified Occupational Therapist trained in workplace postural intervention and inexperienced with the BackTone™ device,
administered the education intervention. Pain, in-task postural angles and opinions about posture were measured using Numerical Rating Scales and on-site, lateral marker imaging. Participants were evaluated at baseline (T0), end of intervention (T1) and 12 weeks follow-up (T2).

Average biofeedback (BF) group pain improvement (63%, SD = 55.95%) was greater than average education (ED) group pain improvement (35.6%, SD = 38.6%) at T1 (p = 0.022) and at T2 (BF 78.1% SD = 57.6%; ED 40.3% SD = 50.5%) (p = 0.048). At T1 there was no difference between BF and ED group improvements in upper-thoracic angle but the BF group achieved larger improvement in cervical angle (p = 0.025). At T2 the BF group achieved larger improvements than the ED group in both upper-thoracic (p = 0.042) and cervical angles (p = 0.007).

The results indicate that use of real-time BBF will enhance outcomes for treatment of computer users with musculoskeletal pain.
Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature: _________________________

Date: 10 December, 2015
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Declaration of Conflict of Interest

The BBF device BackTone™ used in this study was developed by the primary author, Lorraine Josey. Lorraine Josey is a director of BackTone Pty Ltd, which manufactures and markets the BackTone™ device.

Neither of the supervisors (Dr Kieran Broome and Prof Marion Gray) has a conflict of interest in regards to the BackTone™ device.
1: INTRODUCTION

Posture is an important element of safe and optimal human function. Consideration of posture flows through human history with recommendations about posture found in ancient texts such as Sun Tzu’s Art of War (500 BC) and in ancient practices such as yoga and meditation. A focus on posture is included in many aspects of contemporary life from the performing arts to sport, communication and health. The relevance of this focus on posture is supported by research that confirms a relationship between posture and human performance (Finley & Lee, 2003; Kanlayanaphotporn, 2014; Kebaetse, McClure, & Pratt, 1999; Nair, Sagar, Sollers, Consedine, & Broadbent, 2015). Humans are an upright species with an interest and investment in upright postural behaviour.

In recent decades, the rise of computer use has placed added posture-related demands on our everyday life, with a corresponding increase in musculoskeletal disorders (MSD) of the neck, shoulders and upper back (Carroll et al., 2009; Gerr, et al., 2004). Awkward postures are thought to contribute to these problems and consequently many current interventions are based on the premise that they improve posture as a foundation for reducing symptoms of MSD. However, research indicates that current interventions have been largely unsuccessful in reducing symptoms (Brewer, et al., 2006; Kennedy, et al., 2010). Rates of computer-related MSD remain high (Griffiths, et al., 2012).

Although current workplace interventions are based on an effort to improve posture, no workplace-based studies regarding these interventions actually measure spinal posture angles. Given the poor outcomes of workplace-based interventions and since we know that posture and MSD are related, the assumption that current interventions improve posture is doubtful. The question remains: Can we change habitual posture in computer users, and if so, will that improve the symptoms of MSD?

Beyond the field of workplace-based interventions, clinicians have attempted to improve posture with some emerging success using biofeedback. Biofeedback can
be delivered using diverse mechanisms, with varying impacts on behaviour. Exploration of the application of biofeedback in workplaces is warranted since the success of existing strategies is not certain.

The purpose of this thesis is to report on the outcomes of a study of the use of biomechanical biofeedback (BBF) with computer users at the University of the Sunshine Coast and the Sunshine Coast Council in Queensland; conducted between October 2013 and July 2014. The study focused on habitual, real-life, in-task seated posture of regular computer users, rather than posture that may be expressed in a test environment. This approach was selected because in-task posture is thought to be the contributing factor for MSD.

The thesis is organised into five chapters. Chapter 1 provides an Introduction. Chapter 2 reviews the literature relevant to postural evaluation and interventions. The review commences by exploring perspectives on posture and clarifying the nature of postural behaviour under scrutiny in the study. Concepts of postural behaviour which underpin current intervention strategies are discussed. Techniques for measuring posture are described and considered in relation to the target posture. Current strategies for directly changing postural behaviour are explored and critiqued, leading to a closer analysis of biofeedback strategies for modifying posture. The chapter concludes by identifying gaps in the literature and proposing research hypotheses.

Chapter 3 describes the research design including the approach to research, study design, population and samples, data gathering, intervention programs and analysis methods.

Chapter 4 presents the results. It commences with the demographic data, followed by the results of each data gathering.

Chapter 5 discusses the research results with reference to the theoretical foundations and the literature. It also describes the strengths and limitations of the project, recommendations for future research, and discusses the conclusions and implications for clinical practice.
2: LITERATURE REVIEW

Introduction

Musculoskeletal disorders of the neck and upper limb (MSDNUL) form a substantial proportion of health problems and result in a significant social burden in terms of lost productivity, reduced performance and lost-time claims. Prevalence rates for neck and upper limb pain are high (31–44%) in the general population (Bruls, Bastiaenen, & de Bie, 2013; Sim, Lacey, & Lewis, 2006; Walker-Bone, Reading, Coggon, Cooper, & Palmer, 2004; Widanarko et al., 2011) and even higher (56.9–75.7%) in computer users (Cook, et al., 2000; Griffiths, et al., 2012; Ranasinghe et al., 2011).

The annual cost of work-related MSDNUL including sick leave and loss of productivity exceeds billions of dollars in some countries. For example, the cost has been estimated at $45 to $54 billion annually in the United States and €2.1 billion for the Netherlands (Bongers, Ijmker, van den Heuvel & Blatter, 2006). Although significant efforts have been made to reduce the incidence of MSDNUL through workplace interventions, ergonomic modification, training and education, research suggests that the outcomes are mixed: prevalence rates remain high (Griffiths, et al., 2012; Hush, Michaleff, Maher, & Refshauge, 2009). Given the ongoing morbidity associated with MSDNUL, continuing research is required to improve evidence behind interventions and translate evidence into practice.

Neck and upper limb musculoskeletal disorders result from a range of factors including aspects of the person, the environment they work in, and the way in which they complete tasks (Bongers, et al., 2006; da Costa & Vieira, 2010; Gerr et al., 2005; Marcus et al., 2002). Of these factors, posture is considered to be an important independent contributor (Cote et al., 2008; Gerr, et al., 2004; Gerr, Monteilh, & Marcus, 2006). Posture is also considered to be modifiable. Consequently, interventions to reduce MSDNUL frequently aim to improve posture. Strategies used to improve posture include those which directly target changing postural behaviour (posture education and some forms of biofeedback) and those which attempt to achieve postural change indirectly by changing the way an individual interacts posturally with their environment (modification of environment or work demands).
This thesis will focus on techniques which specifically target changing postural behaviour.

To examine techniques for changing posture, we need to be clear about how we define, understand and measure postural behaviour.

**Definition of Posture**

Posture is a complex, dynamic construct which is affected by elements such as habit, task engagement, physical and neurological parameters, and interaction with environment. The term ‘posture’ may refer to body position at a specific moment in time, or it may refer to a general habit of movement behaviours. Haslegrave (1994), in her discussion of working postures, describes the difficulties and complexities involved in forming a definition of posture. She discusses definitions of posture which are based on anatomical and biomechanical constructs as well as definitions that relate to environmental or task factors. An example of the former is Rohmert and Mainzer (as cited in Haslegrave, 1994) who defined posture as a “quasistatic biomechanical alignment”. A further example, though published later, is that put forward by Claus (2009) who defined spinal posture as “the position of spinal segments with respect to each other and with respect to gravity” (p. 404). This type of definition contrasts with task-based definitions such as that put forward by Corlett (as cited in Haslegrave, 1994) who considered posture to be a “position adopted because it is appropriate for the task being performed”. In her review, Haslegrave also notes an inter-relationship between definitions of posture and the measurements used to record postural parameters. She considers that “whatever definition of posture is used, it is essential that the definition facilitates the evaluation of posture factors in relation to task demands” (p. 785). This viewpoint emphasises the importance of clearly defining the target postural behaviour for researchers and highlights the interplay of physiological parameters and task or environmental factors.

The present study is concerned with in-task upper body spinal posture (UBSP) of computer workers. For the purposes of the study, UBSP is defined as the average cervical and upper-thoracic sagittal spinal angles adopted by participants over a 16-minute period of everyday, forward-facing computer work. This definition was
thought to follow measurement approaches used in other studies (Falla, Jull, Russell, Vicenzino, & Hodges, 2007; Golebowicz, Levanon, Palti, & Ratzon, 2015), has been shown to have acceptable psychometric properties (Lau et al., 2010) and was operationally practical.

**How Postural Behaviour Works**

Strategies for modifying postural behaviour are necessarily underpinned by assumptions about the nature of postural behaviour and the processes by which posture is physically expressed. For example, using education to improve habitual posture assumes that individuals frequently monitor or check their posture and make a decision about whether to correct it. An education program would therefore aim to change the frequency or accuracy of postural checking and modify the decision-making process. If equipment and environmental modification were used to modify posture, it is assumed that posture is the result largely of interaction with the environment and intervention focuses on changing the environment and work demands. If exercise is used to modify posture the underlying assumption is that postural behaviour is the result of a balance of muscle forces. The exercise program then focuses on stretching the shortened muscles and strengthening the weakened muscles in the involved area (Hrysomallis & Goodman, 2001; Seidi, Rajabi, Ebrahimi, Alizadeh, & Minoonejad, 2014). These processes are reflected in many existing interventions for management of MSDNUL and are based on the premise that they result in habitual changes towards the neutral posture, thereby reducing risk for MSDNUL (Baker & Moehling, 2013; Gerr et al., 2010; Pillastrini et al., 2010).

Research into the effectiveness of existing workplace interventions in reducing MSDNUL has found mixed results (Brewer, et al., 2006; Kennedy, et al., 2010). Brewer et al. (2006) conducted a systematic review of workplace interventions to prevent musculoskeletal and visual problems in computer users. They found mixed evidence for the effects of ergonomic interventions on these problems. With respect to specific interventions, they found moderate evidence that workstation adjustment, rest breaks and exercise had no effect. They also found a positive effect of alternative pointing devices (alternative mouse designs), although they reported that the pointing devices
studied were limited in number and varied in concept. The review by Brewer et al. (2006) did not support any existing intervention other than alternative pointing devices. Kennedy et al. (2010) conducted a systematic review relating to the question “Do occupational health and safety interventions have an effect on upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time?”. They looked at interventions in studies conducted in the workplace only and did not include studies conducted in other settings. They found that “across all interventions, the results suggest a mixed level of evidence for the effect of occupational health and safety interventions on upper extremity musculoskeletal disorder outcomes” (Kennedy et al., 2010, p. 155). When considering individual interventions, they reported limited evidence supporting combined workstation adjustment and ergonomic training. They also reported that a moderate level of evidence was found for biofeedback training and job stress management training having no effect on upper extremity musculoskeletal outcomes. However, it is noteworthy that the authors only considered one type of biofeedback, electromyographic biofeedback, yet the wording of their recommendations appeared to cover all forms of biofeedback.

Baker and Moehling (2013) called into question the assumption that modifying workstation setup to meet the anthropometric characteristics of the user results in adoption of neutral posture. They conducted a cross-sectional study of 74 computer users. They took single lateral marker images after participants had performed five minutes of a standard task at their own work station. They measured cervical, shoulder, elbow and wrist flexion and correlated the angles with musculoskeletal symptoms and with discrepancies between worker anthropometrics and their workstation setup. They found that only keyboard/elbow discrepancy had a significant moderate association with postural variables. They also noted that significant associations between posture and musculoskeletal symptoms were negative, suggesting that workers with less musculoskeletal symptoms had larger discrepancies between anthropometrics and their workstation setup. Their research does not support the assumption that workstation characteristics determine postural behaviour. The
authors note that since this was a cross-sectional study based on single time-shot images, further research is required to illuminate the subject.

There are limited studies regarding the effect of exercise on posture that measure posture in an experimental situation (Falla, et al., 2007; Hrysomallis & Goodman, 2001; Kuo, Tully, & Galea, 2009; Seidi, et al., 2014). But they do not measure posture in a real-life situation and should be interpreted with caution.

Interventions such as education-based training imply that conscious monitoring of posture is a significant component of postural behaviour. Interventions such as ergonomic modification imply that posture occurs largely as a result of environmental factors. Both have achieved mixed success in reducing MSDNUL. The ranges of outcomes in these studies which have some relationship to posture suggests that we may not yet understand the nature of postural behaviour and the processes by which it is expressed.

### Measuring Posture

Upper body posture has been evaluated using a range of techniques including screening tools, in-test measures (radiological examination or technical measuring devices) and lateral marker imaging. These tools may be employed in a test situation or in a real-life setting. This section will consider approaches to measuring posture, particularly real-life, in-task posture.

#### Screening Tools

Screening tools such as the Rapid Upper Limb Assessment (RULA) (McAtamney & Corlett, 1993) and the Rapid Entire Body Assessment (Hignett & McAtamney, 2000) are used to evaluate an individual’s level of risk for developing upper limb disorders. The RULA can be used whilst observing a worker during performance of their work, or it may be used to evaluate images of workers taken during task performance. The level of risk is calculated based on specific, detailed posture of the upper limbs and gross posture of the head/trunk. In terms of head/trunk posture, it records neck flexion in the following increments: 0–10°, 10–20° and over 20° in relation to the vertical, and
total trunk flexion in 0–20°, 20–60° and over 60° increments in relation to the vertical (See Figure 1).

However, variations of less than 10° neck and thoracic angle have been found to differentiate pain and pain-free subjects. Lau et al (2010) in their study of the relationship between sagittal spinal posture and neck pain, found differences in both cervical and thoracic angles of less than 10° between symptomatic and non-symptomatic groups. Szeto et al. (2005) found a difference between case subjects and control subjects of 3.9° mean neck flexion. Consequently, RULA lacks sufficient sensitivity for measuring changes in spinal posture of therapeutic value.

The rapid entire body assessment (REBA) is similar in nature to RULA. It computes a score that expresses whole-body postural risk and was designed for application to a variety of tasks, including manual handling of people in health care situations. In terms of neck and trunk posture, the REBA records neck flexion in the following increments: 0–20° and over 20° in relation to the vertical, and total trunk flexion in 0–20°, 20–60° and over 60° increments in relation to the vertical. It does not allow discrimination of clinically significant upper body spinal angles, as noted with the RULA.

Although the RULA and REBA are useful screening tools for computing aggregated total body posture risk, they do not allow sufficient discrimination of spinal angles for clinical significance in spinal posture research.
In-Test Measures

Static radiological examination and technical devices such as the Spinal Mouse (Idiag AG, Fehraltorf, Switzerland) or the Zebris WinSpine Pointer (Zebris Medizintechnik GmbH) require application in a research situation. They cannot be used during real-life task performance. These measures require the participant to be stationary, and due to the nature of the test environment, participants are under scrutiny. The measures provide information about spinal angles which is considered to be reliable and has some evidence of validity (Cagnie, Cools, De Loose, Cambier, & Danneels, 2007; Malmstrom, Karlberg, Melander, & Magnusson, 2003; Mannion, Knecht, Balaban, Dvorak, & Grob, 2004). However, it is not clear that these processes actually reflect in-task, habitual posture, as participants posture may change over time and they may adopt non-habitual postures under scrutiny.

Falla, Jull, Russell, Vicenzino and Hodges (2007) noted changes in neck and thoracic posture during a 10 minute computing task. Their study evaluated the effects of different exercise regimes on ability to maintain sitting posture. Participants sat at a computer station in an experimental environment. They were positioned by the researcher in an upright neutral posture and asked to maintain the position whilst they were distracted by playing the game of Solitaire on the computer for 10 minutes. They found that all 68 of their subjects (including the pain-free controls) increased their thoracic angle progressively throughout the 10-minute computer task. Szeto, Straker and O’Sullivan (2005), in their study of neck and shoulder kinematics in symptomatic and asymptomatic office workers, also found changes in neck posture over one hour of computer work. This change in posture over time while engaged in activity may reflect what occurs in real-life, daily activities.

Sigurdsson, Ring, Needham, Boscoe, & Silverman (2011) looked at posture training at mock workstations and the resultant posture in subjects’ own work settings. They found that generalisation of the postural behaviour learned at the mock workstation to the actual work setting was limited. Sigurdsson’s study calls into question whether postural behaviour measured in mock workstations reflects what occurs in the actual work setting. It is possible that in-test postural measurement
strategies, whilst providing important information about specific aspects of posture, may not provide data about real-life postural behaviour. Measuring posture over time and during real-life activity may provide additional useful information.

**Lateral Marker Imaging**

A number of studies measure posture taken from lateral marker images of subjects who have been asked to adopt a certain posture (Seah et al., 2011; Silva, Punt, Sharples, Vilas-Boas, & Johnson, 2009; Straker, O'Sullivan, Smith, & Perry, 2007). Lateral marker imaging involves applying markers to selected anatomical landmarks on a study participant, setting them up as required for the study and taking images from a predetermined camera position at predetermined time points (see Figure 2). Angles are taken from lines drawn between the markers and other environmental or anatomical references (see Figure 3).

Lau et al. (2010) conducted a correlation study exploring relationships between sagittal postures and neck symptoms using lateral marker imaging (see Figure 3). In the same study, they examined the psychometric properties of photographic measurement of the sagittal posture of the thoracic and cervical spine. Forty-five subjects without neck pain and 47 subjects with neck pain were photographed and their upper thoracic and cervical postures were measured following a procedure by Falla et al. (2007). They reported the method showed a high intra-rater and inter-rater reliability in measuring the sagittal postures of thoracic (0.8 – 0.86) and cervical spine (0.81 – 0.87). The Standard Errors of Measurement on the upper thoracic angle and CV angle were 1.00 and 1.30. Lateral marker imaging was found to be a useful, reliable tool for measuring sagittal spinal posture (Lau, et al., 2010).

Lateral marker imaging has also been used to measure spinal angles in a number of studies where the measurements are taken in an experimental setup (Falla, et al., 2007; Kietrys, McClure, & Fitzgerald, 1998; Seah, et al., 2011; Straker, et al., 2007). Baker and Moehling (2013) used lateral marker imaging to measure postural angles at participant’s usual workstation, suggesting applicability in workplace environments.
Figure 2: Lateral Marker Images (Seah, 2011, p. 503)

Figure 3: Measurement of Spinal Angles from Later Marker Image (Lau, 2010, p. 458)
In summary, existing screening tools such as RULA and REBA do not allow discrimination of spinal angles that are clinically significant for pain studies. In-test measuring devices such as radiological examination, the Spinal Mouse or the Zebris WinSpine Pointer may not provide data that is representative of real-life postural behaviour since posture may change over time and may also differ when the subject is under scrutiny. In contrast, lateral marker imaging is a reliable tool for measuring posture and sensitive enough to differentiate between spinal postures that are clinically significant. Lateral marker imaging has also been used in real-life settings and for gathering data over a length of time, during which participant postures may vary.

Consideration of a Suitable Postural Goal

‘Neutral’ posture is widely considered to be the ideal postural goal as it is believed to place people at least risk of injury. However some uncertainty exists regarding the nature of neutral posture. O’Sullivan, O’Sullivan, O’Sullivan & Dankaerts (2012) in a survey of 295 physiotherapists across four European countries found disagreement on what constitutes a neutral spine posture and what is the best sitting posture. Furthermore radiological studies of sagittal spinal angles in a range of populations report a large degree of normal variability in the sagittal alignment of the spine in young healthy volunteers, in middle- and older-aged patients and in patients with back pain (Roussouly, Gollogly, Berthonnaud, & Dimnet, 2005).

Nonetheless more upright thoracic and neck postural angles have been found to be associated with less pain (Falla, et al., 2007; Lau, et al., 2010; Silva, et al., 2009; Yip, Chiu, & Poon, 2008) and it is widely accepted that a more-upright posture in seated computer work reduces risk of MSDNUL (Gerr, et al., 2004; Grandjean, 1988; McAtamney & Corlett, 1993).

Given the potential uncertainty regarding the exact nature of the ‘neutral’ posture, the wide variability of sagittal spinal angles in normal adults and bearing in mind the acknowledged relationship between more upright posture and less pain, for the purposes of this study, more upright cervical and thoracic angles rather than specific values for cervical and thoracic angles will be the goal of the intervention.
Current Strategies that Directly Target Postural Change

This section will describe current interventions which target postural change. The section will also discuss education and exercise followed by biofeedback in the form of electromyographic, visual and biomechanically-based systems.

Education-Based Techniques and Exercise for Retraining Posture

Education-based strategies are widely used for modifying posture in workplace programs to reduce MSDNUL (Brewer, et al., 2006; Kennedy, et al., 2010). In the clinical setting, postural education is also commonly used. Perriman et al. (2012) explored physiotherapy practice in relation to the assessment and treatment of thoracic hyperkyphosis in Australia. They surveyed 220 physiotherapists with predominantly musculoskeletal practices. The most common strategy used to treat thoracic hyperkyphosis was postural education (90%), followed by stretching (71%), strengthening (64%) and joint mobilisation (53%).

It is difficult to determine the effectiveness of education alone as a technique for modifying posture because research typically looks at programs which combine posture training with other modalities. Furthermore, few studies measure in-task spinal posture as an outcome.

Jaromi, Nemeth, Kranicz, Laczko and Betlehem (2012) investigated the effectiveness of a combination of postural and ergonomic education and exercise on pain and trunk postures in nurses with chronic low back pain. They compared six, weekly 50-minute sessions of Back School (BS) with six, weekly 50-minute sessions of passive physiotherapy. The BS interventions consisted of 10 minutes of ergonomic training (including in-task postural training and practice), 20 minutes of exercise and 20 minutes of stretching, with the exercises also practised as homework five times weekly. Low back pain was assessed using a single Visual Analogue Scale (VAS). Static standing posture was evaluated using the Zebris WinSpine Pointer Posture method (Zebris CMS-HS – Zebris Medizintechnik GmbH). Data was collected at baseline, at end of intervention, and at six-month and twelve-month follow-ups. Both BS and passive therapy groups improved pain at end of intervention, but only the BS group improvements persisted at six- and twelve-month follow-ups. Improvements in
thoracic and lumbar postures of the BS group were significantly greater than the control group at all data points. The study provides evidence of benefits for nurses in using an intensive combination of education and regular exercise for improving static, in-test spinal posture in comparison to passive therapies. However, it may not be suitable to extrapolate these findings to computer-based workers. Duties of nursing staff vary from those of computer-based workers and may lend themselves to conscious monitoring and planning of postural strategies during activities with high postural risk. For example, manual handling is conducted in a structured, step-by-step manner with ordered steps focusing on executing the motor components of the task. For computer-based workers, tasks which involve postural risk are constant and ongoing, requiring sustained attention to the computer rather than to the execution of the motor elements of the task. In the study by Jaromi et al., the postural measures were not taken during actual task performance and it is difficult to determine the specific impact of the individual components of the program on posture. Falla et al. (2007) looked at the effects of exercise on sitting posture of people with neck pain. They recruited 58 participants with neck pain and randomly allocated them to two different exercise groups. They also recruited 10 control group participants who had no neck pain. Ability to maintain upright neutral posture over 10 minutes of computer work (playing solitaire) at a standardised work setup was measured using lateral marker imaging. To measure postural behaviour, participants were initially positioned in upright, neutral posture by the researchers. They were then photographed every two minutes for ten minutes. Both exercise groups improved their ability to maintain thoracic posture, but only one group improved their ability to maintain cervical posture. The findings demonstrate that the exercise programs changed participants’ ability to maintain upright neutral posture. Further work is required to examine the effects of exercise on real-life, in-task postural behaviour.

The results of these studies emphasise the importance of education and exercise as part of a comprehensive program for improving posture and pain for people with MSDNUL. However, although education and exercise are widely used for changing postural behaviour, there is no published research regarding its effectiveness.
in changing real-life, in-task postural behaviour. Postural education appears to be the most commonly used modality for changing posture.

**Biofeedback as an Intervention for Retraining Posture**

Biofeedback is one modality which has attracted attention for directly targeting postural change. Biofeedback is a technique that measures body functions and gives feedback to the user in order to help them modify their behaviour. Biofeedback intervention studies in relation to posture and/or musculoskeletal disorders (MSD) have examined electromyographic (EMG) feedback systems, visual (webcam) feedback systems and biomechanically-based biofeedback systems (BBF).

Electromyographic systems utilise electrodes placed on the skin to detect information relating to muscle tension. The information is fed back to the user via sound and/or vibration. Visual biofeedback systems use cameras to take images of the user and project them onto their computer screen. BBF systems detect relative movement of body parts and feed that information back to the user. This is usually in the form of an auditory (e.g., buzzer) or tactile (e.g., vibration) cue. EMG feedback has been studied for its effect on symptoms of MSD, as well as some upper limb postural outcomes. Webcam feedback systems have been studied for their effect on upper limb postural risk. BBF feedback systems have been studied for their effect on changes in spinal posture. The relative evidence for each approach is described and compared below.

**Electromyographic (EMG) feedback**

The rationale underpinning EMG feedback is based on work which demonstrates different EMG behaviour in certain muscles of symptomatic subjects when compared with asymptomatic subjects (Levanon, Gefen, Lerman, Givon, & Ratzon, 2012; Sandsjö, Melin, Rissén, Dohns, & Lundberg, 2000; Voerman et al., 2007b). The hypothesis is that EMG feedback training will reduce the tension of the target muscles, thereby reducing symptoms. In EMG studies, subjects are fitted with biofeedback systems which collect EMG information via surface electrodes and give auditory, vibratory or visual feedback when the signal either exceeds a preset threshold or exceeds a time limit for a preset time. Subjects wear the device during
activity over a number of weeks (Kosterink, Huis in’t Veld, Cagnie, Hasenbring, & Vollenbroek-Hutten, 2010; Levanon, et al., 2012; Ma et al., 2011; Sandsjo, Larsman, Huis in ’t Veld, & Vollenbroek-Hutten, 2010; Voerman, et al., 2007b).

**EMG with Ergonomic Intervention**

Some studies compare EMG programs combined with ergonomic interventions with ergonomic interventions alone. Levanon et al. (2012) compared ergonomics intervention accompanied by EMG feedback training, the same ergonomics intervention without EMG feedback and a control group. Sixty-six frequent computer users were divided evenly between the groups. EMG feedback training and ergonomic intervention was delivered via three to six individual weekly training sessions held at the work site. No significant differences were found between the two interventions and no improvement was gained in muscle activity, although both intervention groups achieved a significant reduction in prevalence of MSD compared with the control group ($p = 0.001$). No information is available on measured pain scores.

Voerman et al. (2007b) compared the effects of ambulant EMG training combined with ergonomic counselling (Mfb) with ergonomic counselling alone (EC). Seventy-nine female computer workers reporting neck-shoulder complaints were randomly assigned to Mfb or EC groups and received four weeks of intervention. The ergonomic intervention was delivered via weekly workplace visits. In addition to weekly ergonomic interventions, Mfb participants wore an EMG system for at least eight hours a week (distributed over two hours a day and at least two days a week as a minimum) for the four weeks, while performing their regular work. Weekly face-to-face reviews were conducted. Pain intensity and disability were measured at commencement and end of intervention, and at three- and six-month follow-ups. VAS was used to measure pain in the neck, shoulders and upper back. The Pain Disability Index (Pollard, 1984) was used to measure the impact of pain on ability to participate in life activities. Average VAS pain scores were reported for baseline measures, but were not specified for other data gathering points. Pain intensity and disability were significantly reduced after both interventions and this effect remained at follow-up ($p \leq 0.01$). No differences were observed between the two intervention groups.
Both studies by Levanon et al. and Voerman et al. found no differences between the intervention groups. Levanon et al. (2012) reported that the ergonomic intervention with biofeedback had no unique contribution in comparison to other interventions. Voerman et al. (2007) found no evidence favouring myofeedback training combined with ergonomic counselling over ergonomic counselling alone. The results from both studies suggest no benefit from including myofeedback training with an ergonomic counselling program for people with neck-shoulder musculoskeletal disorders.

**EMG Compared with Adult Learning and Cognitive Behavioural Techniques**

Faucett, Garry, Nadler and Ettare (2002) examined muscle learning therapy using EMG combined with operant conditioning conducted at mock workstations compared with adult learning and cognitive behavioural techniques. They randomly assigned 108 computer users and small assembly workers who had never been diagnosed with a work-related musculoskeletal disorder to one of the intervention groups or a control group. The two intervention groups received six, weekly training sessions, totalling six hours, plus one hour reinforcement sessions at 18 and 32 weeks. Faucett et al. found no difference between the effect of interventions on symptoms, but the EMG group achieved consistently reduced muscle tension at the end of the six-week program and at the 32-week follow-up. In effect, EMG feedback reduced muscle tension but did not significantly change symptoms.

**EMG Compared with Conventional Treatment**

Other studies have compared EMG programs with conventional treatment interventions (Kosterink, et al., 2010; Ma, et al., 2011; Sandsjo, et al., 2010). Kosterink et al. (2010) and Sandsjo et al. (2010) both compared a group who used ambulant EMG feedback monitored via weekly telephone consultations, with a group who continued their conventional treatments without additional interventions. The myofeedback group had face-to-face consultations in the first and last week of the programs. Outcome measures were indices of pain using the VAS and perceived disability using the Pain Disability Index. Clinically important differences for VAS pain scores were set at 1.3 cm based on recommendations by Kelly (2001), Todd (1996) and Voerman et al.
Measures were taken at baseline, at the end of the four-week intervention program and 12 weeks after completion of the intervention.

Sixty-five women with neck and shoulder pain at work participated in the Sandsjo study. Participants were asked to wear their device for at least eight hours per week, distributed over at least two days each week. Sandsjo et al. (2010) reported that both groups achieved a reduction in pain and disability ($p < 0.05$) although there was no difference between the groups. Seventy-one subjects with non-specific, non-work related neck and shoulder pain were included in the Kosterink study. No information is available regarding the wearing regime for their EMG device. Kosterink et al. (2010) also reported that both groups achieved a reduction in pain and disability ($p \leq 0.05$) with no significant difference between the groups. Both authors conclude that ambulant myofeedback monitored by telephone consultations is as effective as conventional interventions.

In both studies however, participants in both the myofeedback and the conventional treatment groups were allowed to continue with their own self-selected interventions such as physiotherapy, acupuncture etc. Sandsjo et al. (2010) explained the ethical reasons why it would be unacceptable to require participants to discontinue on-going treatment in order to take part in the study. They noted that 55% of the myofeedback group and 46% of the conventional care group were involved in treatment at the end of the four-week intervention. Kosterink et al. (2010) noted that 39% of the myofeedback group and 33% of the conventional care group had received physiotherapy for neck and shoulder pain during the four-week intervention. They reported no significant difference in the percentage receiving physiotherapy ($p \geq 0.24$) between the groups. Given that the myofeedback group in both studies appears to have received similar conventional treatments to the conventional care group and there was no difference in the outcomes between the two groups, it is difficult to understand the conclusion that myofeedback monitored by telephone consultation is at least as effective as conventional care. Alternatively, it could be interpreted that there was no evidence favouring myofeedback monitored by telephone consultation
combined with ergonomic counselling over participant-selected conventional treatments.

Ma et al. (2011) compared the use of an EMG system with two conventional physiotherapy programs (active exercises and passive treatments) and a control group. Subjects in the EMG group were taught to reduce upper trapezius muscle activity by slightly depressing the shoulders or by sitting quietly with the eyes closed and the shoulders relaxed. They were reviewed weekly and the feedback threshold of their EMG system was adjusted based on the participant’s average muscle activity during a 10-minute typing task. Pain, disability and surface electromyography were assessed prior to the start of intervention and after the six-week program. Pain and disability only were reassessed after a further six months. All participants received a standard education booklet about office ergonomics. The control group received no intervention other than the education booklet. The authors reported that average pain and disability scores were reduced significantly more in the biofeedback group than in the other three groups, and this was maintained at six months (p < 0.05). Diaries indicated that participants had worn their device for two working hours per day for five to six days every week over the six-week intervention period.

Ma et al. (2011) was the only study to report a difference between the EMG feedback group and the other groups. In their discussion, Ma et al. proposed that the strategy of adjusting the feedback threshold at each weekly review may have an important impact on the outcomes. Differences in wearing regime between this study and other EMG studies may have also played a part in the different outcomes. This study used an initial training session and six weekly follow-up sessions by the therapist, combined with daily two-hour wearing regimes for the EMG participants. Exercise group participants were required to perform four, 20-minute exercise sessions daily in conjunction with the weekly follow-ups. Seventy-two participants commenced the program and 12 dropped out by the end of intervention. A further 22 had dropped out by the six-month follow-up. This high attrition rate may be related to a perceived high cost-benefit ratio of the program.

**Summary of EMG in Workplace Programs**
None of the EMG studies attempted to retrain spinal posture, although Levanon et al. (2012) did seek to retrain some aspects of upper limb posture and evaluated the outcomes with RULA. EMG feedback focuses on retraining behaviour of specific muscles and is based on research regarding EMG behaviour of certain muscles. However, performance of movements and tasks involves a complex interplay of numerous muscles and other anatomic structures. Retraining individual muscles may not take into account this complexity.

EMG feedback has demonstrated application for achieving muscle relaxation, but has not consistently demonstrated improved outcomes for reducing MSD or improving spinal posture when compared with conventional therapies. While the current state-of-the-art research would not support the use of EMG feedback as a workplace-based intervention for treatment of MSD, using EMG to train relaxation of specific muscles may be useful in a clinical setting.

**Visual (Webcam) Feedback**

*Webcam and Ergonomic Counselling*

Visual feedback has been used to retrain posture in computer users with some success. Taieb-Maimon, Cwikel, Shapira and Orenstein (2012) compared the use of a webcam technique in combination with ergonomic counselling against ergonomic counselling alone. Sixty office workers were divided into one control and two intervention groups. Musculoskeletal risk as indicated by the RULA was measured at baseline, during three weeks of intervention and after one week of no intervention. The webcam intervention group achieved significantly better RULA scores than the ergonomic counselling alone group and this persisted after one week of no intervention. There were no other follow-up measurements. The study demonstrated evidence of reduced risk for developing upper limb disorders when using visual feedback, but inferences could not be made about spinal posture since RULA does not measure this in increments small enough to detect clinically significant change. A one-week follow-up period may not be sufficient to predict long-term benefit.

Sigurdsson, Austin and Dixon (2008) took lateral images of eight participants who worked for approximately 20 minutes up to two times per day at a mock
computer workstation. The images were taken at regular intervals and displayed on the participants’ computer screen. An image of the participant in safe work posture, together with a postural self-scoring form was also displayed. Participants were asked to give feedback regarding head/neck, arm, hand-wrist, back and leg positions. The authors reported increases in self-monitoring accuracy of the postural variables; however, the sample size was low and no inferential statistics were applied.

While use of visual feedback systems demonstrates reduced risk for development of upper limb problems, the outcome measures used do not provide sufficiently detailed information about thoracic or cervical curvature. Furthermore, their application is limited to seated computer work only.

**Biomechanical Biofeedback**

Biomechanical biofeedback systems use sensors to measure relative changes in the position of body parts. Some authors have described BBF systems which utilise accelerometers and gyroscopes to give users immediate feedback about motor performance related to postural behaviour (Breen, Nisar, & Olaighin, 2009; Lou, Raso, Hill, Durdle, & Moreau, 2002; W. Y. Wong & Wong, 2008).

Breen et al. (2009) attached an accelerometer to the C7 vertebrae of six regular computer users. The accelerometer measured the angle formed by a line between C7 and the tragus of the ear with the vertical. It was connected to the user’s computer. Two five-hour sessions were recorded. During session one, data was collected and no feedback was provided to the participant. During the second session, feedback was provided when the head/neck angle exceeded a threshold set by the investigator. Auditory feedback in the form of a beep and visual feedback in the form of a replicated image of the participant’s posture appearing on their computer screen was provided. Time spent in undesirable postures was reduced after the biofeedback training and the difference reached statistical significance ($p < 0.05$). However, sample size was low and there was no information about longer term effects.

Wong and Wong (2008) tested the use of a ‘smart garment’ with integrated accelerometers and gyroscopes that measured spinal curvature variations in the sagittal and coronal planes. Five participants wore the garments for two hours daily...
over four days, during their leisure time. The feedback function was disabled during days one and four to allow for data gathering. The primary outcome measure was time spent in undesirable postures, and this was significantly reduced during the sessions with feedback enabled \( (p = 0.039) \).

Lou, Raso, Hill, Durdle and Moreau (2002) investigated the use of an accelerometer attached to the subject at the T3 level and connected via cable to a microprocessor clipped to the subject’s belt. The accelerometer measured inclination in relation to the vertical and the microprocessor emitted a buzz for two seconds when the angle exceeded a preset limit. Subjects wore the system for at least six hours during normal activities over two days, with no feedback on day one. The outcome measure was frequency of trunk angles exceeding the preset limit. Although they reported desirable changes, no statistical procedures were applied.

The sample size was low in each of these studies, with the largest sample being six participants in the study by Breen et al. (2009). As a result, generalisation of the findings may be limited.

**Posture Training and Idiopathic Adolescent Scoliosis**

Biomechanical biofeedback has also been used in the treatment of idiopathic adolescent scoliosis. Dworkin et al. (1985) described a BBF system consisting of a harness made of thin nylon cord positioned circumferentially around the vertical axis of the abdomen with an electronic unit attached. The harness lengthened as the wearer extended the major axis of the body by straightening the spine. Reducing the major axis of the body was defined as incorrect posture. The feedback mechanism was designed so that adoption of incorrect posture resulted in the electronic unit producing a tone that increased in volume over a period of 20 seconds.

The device was fitted to 12 adolescents who were diagnosed with progressively deteriorating spinal curves, and were on the verge of requiring bracing as judged by their referring orthopaedists. The device was worn for up to 23 hours per day. Two of the adolescents were withdrawn from the study by their referring orthopaedist and fitted with braces. The remaining 10 participants achieved improvements in radiological measures of their scoliosis to the extent that the deterioration of their
spinal curves was halted. Average starting and ending Cobb angles showed a 1° improvement for the group, although no inferential statistical procedures were applied. The fact that 10 of the 12 subjects were discharged from the treatment program because the progression of their spinal curves was halted provides promise that this type of biofeedback may be successful in changing posture.

Birbaumer, Flor, Cevey, Dworkin and Miller (1994) used the same device with 27 patients with progressive idiopathic juvenile scoliosis (19) or kyphosis (8). Subjects wore the device for up to eight hours per day. Authors noted that due to the natural progression of the disease, it seemed ethically problematic to use a matched control group without treatment. However, for the purpose of statistical comparison, five of the subjects who did not comply with the wearing regime were viewed as controls. Compliant subjects achieved a significant improvement in spinal curvature as measured radiologically, whereas noncompliance (the control group) resulted in deterioration of curvatures ($p < 0.01$). No information is available about why the control group did not comply with the wearing regime.

Wong, Mak, Luk, Evans and Brown (2001) used the same system with 16 subjects who were diagnosed with adolescent idiopathic scoliosis (AIS) and whose spinal curves were either increasing or were large with a high risk of further increase. The aim of their 18-month program was to prevent further increases in spinal curves. Three subjects withdrew within the first three months and four showed curve progression (two changed to rigid spinal orthoses and two underwent surgery). Of the remaining nine participants, five reached skeletal maturity and terminated the application and four continued until skeletal maturity. Radiological and anthropometric measurements were taken pre-application and at every three-monthly review. They compared curve progression pre-program and over the 18 months. No statistically significant differences were found between the pre-application spinal curves and those at the six successive visits for the nine subjects who continued to use the device, even though their curves had been progressing prior to inclusion in the program. The lack of progression of spinal angles meets the criterion of effective control using the postural training device.
The emerging evidence for the use of BBF in changing spinal curvature suggests it may have potential in changing posture of people in other settings.

**BBF and Retraining of Functional Tasks**

Dean and Dean (2006) described a functional biofeedback system which gave information regarding degree of lumbar curvature. They used it to educate wearers about posture during a manual handling task: lifting a golf bag from a car boot. Twenty-five golfers were fitted with the device which measured lumbar curvature and could be set to record information and give an auditory and vibrational alert when the lumbar curve exceeded 20°. The study was conducted over three days. Baseline and follow-up measures were taken on days one and three, recording posture but without providing feedback. On day two, the task was performed three times with biofeedback. Outcome measures were the number of times the device was activated and duration of time it was activated. There was a significant difference in number of activations (p < 0.004) and duration of activations (p < 0.001) from baseline to day 3. Although the intervention was of short duration, and there was no control group or follow-up, the outcomes suggest promising potential for the use of BBF in retraining postural behaviour.

**Low Back Pain**

O’Sullivan, O’Sullivan, O’Sullivan and Dankaerts (2013) explored the use of a BBF system for modifying postural behaviour in people with non-specific chronic low back pain. Twenty-four participants were recruited. Baseline pain, disability and posture were evaluated over a two-hour seated task (watching a DVD while sitting continuously on a leather stool without a backrest). Sixteen participants whose Low Back Discomfort (LBD) increased by at least two points on a Numerical Rating Scale during the baseline task were provided with a biofeedback intervention. The intervention consisted of performing the same task one week later with BBF matched to their postural behaviour. For the intervention group, increase in LBD during the task was reduced by modifying their sitting behaviour according to their individual clinical presentation using the BBF (p = 0.002). The authors also reported significant changes in lumbo-sacral posture when considered in relation to the nature of individual
postural behaviour (p < 0.001). The magnitude of pain change was small and there was no follow-up of participants. O’Sullivan et al. noted that the study provided preliminary evidence of a role for postural BBF in treating people with non-specific chronic low back pain, but further research is recommended.

Magnusson (2008) looked at the use of BBF in treating people with low back pain. Forty-seven participants with chronic low back pain were randomly divided between two treatment groups. One group received a standard rehabilitation program and the other group received both the standard program and additional ‘guided motion’ biofeedback training using a “Back Tracker in tethered mode” (p. E543). The researchers reported that the biofeedback group achieved significantly better outcomes in terms of measures of pain, mobility and function, and the difference persisted at a six-month follow-up. They did not measure posture.

**Comparison of Evidence for EMG, Visual and Biomechanical Biofeedback**

Biofeedback in the form of EMG feedback, webcam feedback and biomechanical feedback has been used to retrain posture and ameliorate symptoms related to MSD. While in some studies, EMG feedback changed levels of muscle activation, it did not consistently reduce symptoms in comparison to other existing interventions. Visual feedback has been used to reduce risk for development of upper limb disorders, but we cannot draw conclusions about its effect on spinal postures. An additional limitation of visual biofeedback systems is that they are restricted to seated computer work. BBF systems have demonstrated some potential in retraining postural behaviour, both in seated and moving tasks, but there were limitations in the studies in relation to small sample size, outcome measures, short duration of some of the interventions and lack of controls.

The state-of-the-art research suggests that neither EMG nor visual feedback have sufficient or consistent evidence to address the issue of postural retraining. BBF may be a viable alternative for changing posture and thereby reducing MSD. While there is emerging evidence for the use of BBF, a number of limitations in the existing literature have been identified. Examination of the effectiveness of BBF in retraining posture and reducing the symptoms of MSD may provide clinicians with another useful
tool for reducing the burden of MSD of the neck, upper back, shoulder and arms. Given the complex nature of postural behaviour, additional exploration of peoples’ beliefs and opinions about posture may provide valuable insights.

**Opinions about Posture Behaviour**

The variety and complexity of knowledge about postural behaviour, the range of interventions relating to it and the mixed outcomes associated with these interventions, beg the question “What do participants think about posture and postural retraining?”. The question is important because regardless of the modality chosen for modifying postural behaviour, the participants’ compliance will have an effect on the success of the program. Compliance may be affected by participant’s belief in the intervention. Moreover, if a person believes that modifying their posture will affect their pain symptoms, and if they feel a degree of confidence in their ability to change their posture, they may develop some capacity to manage and reduce pain related to MSDNUL in the future by implementing their posture retraining strategies. Providing people with tools to modify their symptoms by changing their own postural behaviour has yet to be tested.

**Research Aim and Hypotheses**

The aim of the present study was to compare the effectiveness of real-time BBF with current posture education practice in reducing pain and improving upper body posture in computer users. An additional aim was to explore relationships between participants’ beliefs and opinions about posture in relation to actual changes in posture or pain. It was hypothesised that:

1. Computer users who undergo a BBF training program will achieve greater improvement in neck, shoulder and upper back pain scores than computer users who undergo a traditional posture retraining program.

2. Computer users who undergo a BBF training program will demonstrate greater improvements in upper-thoracic and cervical spinal angles than computer users who undergo a traditional posture retraining program.
3. Computer user’s upper-thoracic and cervical spinal angles will correlate with their self-assessment of their frequency of slouching.

4. Computer user’s neck, shoulder and upper back pain will correlate with their self-assessment of their frequency of slouching.

5. Computer users who reduce their neck, shoulder and upper back pain will report that they consider there is a stronger relationship between posture and pain.

6. Computer users with greater improvements in neck, shoulder and upper back pain will report higher belief in their ability to change their posture than those with smaller improvements in neck, shoulder and upper back pain.
3: METHODOLOGY

This chapter describes the research design including approach to the research, study design, methodology, participants, ethics, and data collection and analysis methods.

Approach to the Research

The study attempted to minimise the potential influence of the researcher and the research environment on measurement of posture behaviour and thereby gain an understanding of aspects of real-life postural behaviour. Accordingly, a number of strategies were used to gather data that was more likely to reflect real-life behaviour.

- All data gathering and interventions were wholly conducted in the participant’s workplace.
- Participants were videoed at their usual workstation, even if they had changed desks, offices or work location during the course of the study.
- Participants were videoed while they performed their usual work tasks rather than a task allocated by the researcher.
- Participants were videoed over a period of time and postural results were averaged. The purpose of this strategy was twofold: to allow participants time to settle into their usual posture and to account for possible changes in posture that may occur over time as noted in previous studies (Falla, et al., 2007; Szeto, et al., 2005).

Research Design

A randomised-controlled, matched-pairs, block design was utilised. All participants completed the same assessments at baseline (T0). In order to form two very similar blocks, the participants were matched to pairs according to the results of their baseline assessments and then randomly allocated to one of two intervention groups: a biofeedback group who underwent a real-time biomechanical postural biofeedback program and a conventional education group who underwent an on-site postural education program from an occupational therapist. The intervention programs lasted for three weeks, after which participants were reassessed (T1).
Volunteers assessed for eligibility (n = 50)

Excluded (total n = 8)
Health reasons (n = 2)
Age (n = 1)
Logistical reasons (schedule clashes) (n = 5)

Enrolment and baseline data gathering (T0) (n=42)

Scoring, ranking and pairing
Random allocation to treatment groups

Biofeedback group (n = 21)

Education group (n = 21)

2 pairs withdrew

End of intervention data gathering (T1)

Follow-up data gathering (T2)

1 pair excluded from analysis because of previously-undisclosed health problem

Scoring, analysis and interpretation of results (n=18 in each group)

Figure 4: Progress Through the Study
A follow-up assessment was conducted again after a further 12 weeks (T2). Figure 4 illustrates the progression of subjects through the study.

The education intervention was used as a ‘usual’ practice control group. On-site education is an accepted, existing practice for retraining posture and reducing neck, upper back and arm pain (Gravina, Lindstrom-Hazel, & Austin, 2007; Kennedy, et al., 2010; Ketola et al., 2002; Levanon, et al., 2012; Voerman, et al., 2007b). Given the inclusion of current practice as one of the interventions, a ‘no intervention’ control group was considered unnecessary.

**Piloting of the Methods**

In preparation for this research project, a pilot quality assurance project was conducted in 2006 exploring the use of the biofeedback device with eight staff at a local hospital. Staff attended an hour long lecture about posture and were then individually fitted with a biofeedback device. They were loaned the device for a period of 4–6 weeks. Individual follow-up occurred every 1–2 weeks as required. Participants wore their device for 20–30 mins, one to three times daily during performance of their usual tasks at home and/or work.

Participants evaluated their overall habitual posture by indicating their frequency of slouching on a Numerical Rating Scale (NRS). They also assessed musculoskeletal symptoms using NRSs. These assessments were taken at commencement of the program, at end of the program, and six months after completion of the program.

Outcomes from the program were examined as a pilot project to inform the design of the present study. The results indicated that:

- No participant reported any adverse event or difficulty relating to the program or equipment.
- There were 43 reports of symptoms throughout the program. Thirty-seven symptom scores reduced or disappeared at the end of the six weeks. Thirty-three of these remained low or were lower at six months.
• All participants reported reduced slouching frequency over the course of the program. At six months, all slouching self-assessment scores continued to be well below those at commencement of the program.

A combined NRS scores for Neck, Shoulder and Upper-Back pain from the pilot project was used to inform sample size for the current study.

Population and Samples

Adult computer-based workers with pain in their neck, shoulders or upper back were the population of interest. Regular computer users at two large multi-site local employers (one university with 821 staff and one local government with 2300 staff) were considered representative of the population of interest. Participation in the study was available to all staff, so long as they met inclusion/exclusion criteria. Similar studies have used staff of government offices, private companies and universities for samples (Chiu et al., 2002; Cho, Hwang, & Cherng, 2012; Faucett, et al., 2002; Griffiths, et al., 2012; Park & Yoo, 2012).

Power Calculation

The power calculation for sample size was conducted using the G*Power program version 3.1.9.2 (Franz Faul Universitat, Kiel, Germany). End of Intervention change in total neck, shoulder and upper back pain score from the pilot study was used for the power calculation because change in total neck, shoulder and upper back pain was the primary outcome measure. Mean change in neck, shoulder and upper back pain of 4.4 (SD = 3.2) with a two-sided significance of 0.05 and a power of 0.95 was used to inform the calculation. The power calculation indicated that a total of 10 pairs would be required.

Recruitment

Participants were recruited from academic and administrative staff of the University of the Sunshine Coast in Queensland, Australia and from staff at Sunshine Coast Council who used computers on a daily basis. Both employers are large multi-site organisations and participants came from 36 separate venues. Recruitment occurred between September and November 2013. Staff were notified about the study via email,
flyers and newsletters. Volunteers made contact via email to the primary researcher and were sent project information handouts and participant screening questionnaires for completion and return. Volunteers were screened via the emailed questionnaire and a follow-up phone call to clarify information where necessary. Volunteers who did not meet eligibility criteria were advised by email. Volunteers who met the eligibility criteria were invited to participate and were sent consent forms.

Involvement in the project constituted a considerable commitment by participants as they were required to be available for a total of five visits (two intervention and three data collection visits) by researchers over a 16-week period and also had to commit to implementing the intervention strategies. Participants were not paid for participation in this study, although the BF group were allowed to keep their BBF device after completion of the study.

Data was collected between September 2013 and June 2014. University of the Sunshine Coast staff were recruited initially, but when it became apparent that an additional source was needed to recruit sufficient numbers, Sunshine Coast Council was approached and gave permission for staff to be involved in the project.

**Inclusion and Exclusion Criteria**

Inclusion and exclusion criteria were determined with reference to other studies which evaluated biofeedback interventions for workers with pain in the neck, upper back and arm (Levanon, et al., 2012; Ma, et al., 2011; Voerman, et al., 2007b). The inclusion criteria were as follows: aged between 18 and 60 years; working 20 hours or more per week; use of computer every working day; neck, upper back or shoulder pain in the previous seven days; neck, upper back or shoulder pain in at least 30 days over the previous 12 months. Participants were excluded if they had been diagnosed with inflammatory conditions; neurological conditions; or medical conditions that may cause pain, numbness or swelling. All participants gave their informed consent prior to participation.
Data Gathering Instruments

Demographics

Participants provided information about their age, gender, working hours, employer and medical history when completing the screening questionnaire. They provided height and weight data during the initial assessment.

The following data was gathered from each participant via two questionnaires and video imaging at T0, T1 and T2:

- Pain in a number of body regions
- Self-assessment of their postural status, opinion about the degree of impact changing their posture will have on their pain and self-assessment of their ability to change their posture
- Frequency and success of implementing the program strategies
- Upper thoracic angle in relation to the thoracic (Th) horizontal when looking directly at the screen, averaged over a 16-minute period
- Cervical angle in relation to the C7 horizontal when looking directly at the screen, averaged over a 16-minute period

Outcomes

The primary outcome was change in neck, shoulder and upper-back pain, computed from NRSs. Secondary outcomes were change in cervical and upper-thoracic angle taken from lateral marker images, and beliefs relating to posture taken from NRSs. All outcome measures were delivered in the workplace at T0, T1 and T2.

Outcomes Measures: Questionnaires

*Measurement of Pain*

Participants evaluated their pain in body regions based on the body regions used in the Standardised Nordic Questionnaire (SNQ) (Kuorinka et al., 1987). The NRS format used was a 10 cm horizontal line with markings and corresponding numerals at each centimetre (0–10). The NRS is widely used for evaluating pain, including
musculoskeletal pain. It has high test-retest reliability and construct validity, with good capability for statistical analysis (Farrar, Young, LaMoreaux, Werth, & Poole, 2001; Salaffi, Stancati, Silvestri, Ciapetti, & Grassi, 2004; Williamson & Hoggart, 2005). Salaffi et al. (2004) recommended a raw value change of 2.0 cm or 33% in NRS score to be best associated with the clinical concept of “much better” improvement. Similarly, Farrar et al. (2001) recommended a reduction of 2 points or approximately 30% to represent a clinically important difference.

The SNQ evaluates the presence of musculoskeletal symptoms in a number of body regions (Kuorinka, et al., 1987). It is used in ergonomic and occupational health contexts. The SNQ uses a whole body diagram to identify the following areas for consideration of pain levels: neck, shoulders, upper back, elbows, wrist/hands, low back, hips/thighs, knees and ankles/feet. The SNQ whole body diagram was utilised to encourage consistency by participants when evaluating pain across various body regions. For the purposes of this study, the hips/thighs, knees and ankles/feet were combined into one item called legs/knees/feet. Questions from the original SNQ were not used because they only provide information about the presence (or absence) of pain without an assessment of degree of pain. A short questionnaire utilising NRSs for evaluating pain across body regions based on the SNQ was formulated (Appendix D).

Measurement of Beliefs Relating to Posture

Participants were also asked questions designed to elicit information about the strength of their beliefs or opinions relating to posture. Participants were asked to rate their responses to the following questions on NRSs:

- “How often do you slouch or stoop?” anchored by “Virtually never” and “All the time”.
- “What difference will changing posture make to your pain or discomfort?” anchored by “No difference at all” and “My pain will go”.
- “How effective are you at changing your posture habit?” anchored by “I can’t change my posture” and “I am able to change my posture”.

Success in Use of Program Techniques
Biofeedback (BBF) group participants were supplied with a wearing diary to complete during the three-week intervention. At T1, BBF participants were also asked to rate how well they had implemented their BBF wearing regime using an NRS anchored by “No success” and “I was completely successful”. At T1, education (ED) group participants were asked to rate how well they were able to implement their strategies for changing their posture using an NRS anchored by “Not at all” and “All the time”.

At T2, BBF participants were asked if they had worn their BackTone™ since the previous contact and if so, how many times. ED participants were asked if they had utilised any of the posture correction techniques since the previous contact and if so, how often. It was not considered feasible for ED group participants to complete a diary detailing their use of the strategies because doing so may have influenced the actual behaviour. BF group participants were not asked about posture correction strategies during the follow-up period because they had not been taught any.

See Appendices E to J for questionnaires and wearing diary.

**Outcome Measures: Video Imaging**

The present study is concerned with the in-task, upper body spinal posture (UBSP) of computer workers. Operationally, this was defined as “the average cervical and upper-thoracic sagittal spinal angles adopted by computer-based workers over a 16-minute period of their everyday, forward-facing computer work”. In particular, the study is interested in the angles between cervical spine and the horizontal and between the upper thoracic angle and the horizontal. These angles were chosen because:

- They follow measurement approaches used in other studies (Falla, et al., 2007; Golebowicz, et al., 2015).
- The approach has been shown to have acceptable psychometric properties (Lau, et al., 2010).
- Increases in these angles have been shown to correlate with reductions in pain (Falla, et al., 2007; Lau, et al., 2010; Yip, et al., 2008) and
• The anatomical points chosen have practical applicability at a real-life computer work station.

Consideration was given to comparing thoracic and cervical angles with a ‘normal’ range but researchers suggest that the span of possible values of maximum kyphosis in subjects with no spinal disease is considerable and it is therefore unreasonable to speak of normal kyphotic curves (Stagnara et al. in Roussouly, Gollogly, Berthonnaud, & Dimnet, 2005). A decision was made to compare changes in spinal angles, with an increase in angle being the desirable goal.

Sixteen minutes of videoing was selected because it was longer than a previously-studied 10 minutes of computer related sitting posture (Falla, et al., 2007), but fitted in with operational demands.

Spherical polystyrene markers of 22 mm diameter were attached using double-sided tape to the tragus of their ear, the spinous process of C7 and the midpoint of the superior border of the manubrium. Ideally comparison of a thoracic angle (T3-C7) would be made in relation to a lumbar marker however this was not possible since participants sat in chairs with back supports and lumbar markers were not visible. A decision was made to measure the angle in relation to an external horizontal because other authors have similarly measured the cervical and/or thoracic angles in relation to an external horizontal or vertical (Falla 2007, Gaffney 2014, Lau 2010, Silva 2009, Straker 2007). Attempts to attach the markers to the spinous process of T3 were unsuccessful because loose clothing buckled and moved the marker in relation to the T3 spinous process as the participant leaned forward and back in relation to their backrest. An alternative method for locating a fixed thoracic point was devised and is described later. T3 was chosen as the thoracic marking point because lower thoracic levels were not visible in work chairs with back rests (Figure 5). A marker was placed on the Acromion process but was not used for this study. A small video camera mounted on a tripod was set up as close as possible to the following position: 1.5 metres from the chair, with the lens at right angles to the sagittal plane and at the same height as the participant’s seventh cervical vertebrae. Participants were asked to continue with their usual work and were videoed for 16–20 minutes. Participants in
the BF group did not wear the device during any of the data collection or videoing. Still images were drawn from the videos at two minute intervals.

![Figure 5: Setup of markers: Tragus of the ear, C7, T3, Upper border of Manubrium and Acromion process (not used in this study)](image)

**Ranking, Pairing and Block Allocation**

After recruitment, participants were de-identified and allocated a participant identification number. Their baseline assessments were scored. The primary supervisor, blinded to participant identity, ranked, paired and allocated participants to treatment groups. Participants were ranked using an Excel™ algorithm according to their scores on the following criteria in descending weight: neck pain, shoulder pain, upper back pain. The ranking procedure produced a single list with participants ranked from highest to lowest in descending order of the above-mentioned scores. Immediately adjacent participants on the ranked list were paired and then allocated randomly to one of the two intervention groups. Both participants and care-givers were blinded to the group assignment process. Blinding of intervention delivery was not possible due to the nature of the interventions.

**Rationale for Ranking and Pairing**

Baseline pain severity was chosen as the primary pairing criteria because it is a known predictor of prognosis in neck pain sufferers (Borghouts, Koes, & Bouter, 1998). It is also considered to be a strong determinant of mental and physical functional status (Ang, Kroenke, & McHorney, 2006). Neck pain was selected as the primary
ranking criteria because the relationship between severity of neck pain and posture of the neck and thoracic region has been well established in a number of studies (Falla, et al., 2007; Lau, et al., 2010; Yip, et al., 2008). Griegel-Morris, Larson, Mueller-Klaus & Oatis (1992) included pain in the upper thoracic region in their exploration of the association between incidence of common postural problems and pain. They found a relationship between incidence of increased thoracic kyphosis and incidence of intrascapular pain, but they did not find a relationship between the severity of the kyphosis and the severity of the pain.

Scoring levels on the NRS were considered important in the pair allocation process because what is thought to be a clinically significant difference in pain score varies across the NRS scale. In order to achieve a minimally important clinical difference, respondents who score at the higher end of the scale at baseline measurement (> 7.0 cm) require a larger change in raw score than do respondents who score at the lower end of the scale (< 4.0 cm) (Salaffi, et al., 2004). Consequently, it was considered appropriate to evenly match participants across the two groups according to baseline severity of pain and the degree of measured change which would be considered clinically significant.

Interventions

All participants were provided with handouts which gave general information about posture and outlined recommended ergonomic workstation setup. The workstation setup advice was from Safety, Health and Wellbeing, The University of Western Australia (2012) (Appendix M). Interventions occurred between December 2013 and July 2014.

The Biofeedback Program

The approach for the BBF group was to use real-time biofeedback during task performance to change the way participants perform the task rather than to require them to try and remember to check their posture and enact postural correction techniques. The approach aims to focus more on automation of the movements
inherent to performance of the task rather than cognitive monitoring of motor behaviours. BF group participants were not taught posture correction strategies.

Participants in the biofeedback group were fitted with a BackTone 4000 posture trainer (BackTone Pty Ltd, Australia). The device was developed by an occupational therapist experienced in the design and manufacture of complex dynamic splints. The device consists of a non-elastic webbing harness which holds an electronic unit longitudinally between the shoulder blades and the waist (Figure 6). The waist belt fits tightly around the waist and cannot slip lower because the length of the belt will not expand to meet the girth of the abdomen below waist level. In this manner the design of the harness precludes detection of thoraco-lumbar curvature, as to do so it would be necessary for the harness to extend below the waist to the lumbar region. When the wearer slouches the upper body (increasing thoracic flexion), the harness pulls on the sensor causing it to beep. To stop the beep, the wearer must straighten up, increasing their cervical and thoracic angles in relation to the horizontal. As noted previously more upright cervical and thoracic angles was chosen as the postural goal for this study.

Since the wearer receives feedback as they perform the movement, BackTone™ is a real-time biofeedback device, providing performance information.

BBF participants were taught how to adopt more upright posture without the device, as this was the target behaviour. They were then taught how to fit the device themselves in order to achieve that posture. They were asked to wear the device one to two times daily while performing their everyday activities for three weeks. In that way, participants incorporated their learnings into everyday performance of their task. They were advised to wear their BackTone™ during sitting tasks as well as standing/walking activities. Participants whose wearing program was interrupted by work schedules, sick days etc. were allowed to continue with the intervention program until they had achieved at least 18 days of wearing the device.

Biofeedback group participants received two 45-minute visits by an occupational therapist: one to fit the device and train them in its use and the other to check how they were going and modify their fitting or program if required. No
ergonomic advice or training and no posture correction or posture habit training strategies were provided to BBF group participants.

At end of intervention, BBF group participants were advised that the intervention program requiring daily use of the BackTone™ had ended. They were now free to use the device at their own discretion.

![Figure 6: BackTone 4000 posture trainer](image)

**The Education (ED) Program**

Participants in the ED group were each given the same generic set of simple instructions in order to maintain research integrity. The instructions were delivered in two practical, on-site sessions by a qualified and registered Occupational Therapist, trained in postural education and inexperienced in using the BackTone™ Posture Trainer. The Occupational Therapist monitored participant performance and modified instructions as required. Participants practised the posture in sitting, standing and walking, under the guidance of the Occupational Therapist in order to ensure they were able to enact the instructions and incorporate them into activity.

The education group received two 45-minute workplace visits from the occupational therapist. The intensity of the program was equal to the BBF group. The content of the sessions included:
1. Education about anatomical, physiological and mechanical issues in relation to posture.
2. Practical training towards neutral posture adjustment. Participants were taught to adjust their posture by implementing the following instructions:
   a. Think about your sternum and lift it up towards the ceiling.
   b. Imagine a string attached to the base (back) of your skull and lift up through the string.
   c. Think about your tummy and activate your tummy muscles slightly (about 1/10th of a contraction).
   d. Relax or drop your shoulders
   e. Relax your neck muscles and imagine balancing your head on top of your neck like balancing a ball on top of a cone.
3. Reinforcement in sitting, standing and moving. Participants practised posture correction strategies in sitting and standing while monitored by the occupational therapist. They also practised maintaining that posture while leaning forward (as if to reach items on their desk) and walking.
4. Reminders. Personalised reminders suited to each participant were developed to aid them in checking and correcting their posture throughout the day. For example, sticky notes with personalised cues were placed in positions critical to the individual worker.

The first visit by the occupational therapist involved provision of training, and the second visit involved review and modification of strategies as required. Workplace-based education involving practical training was chosen because this approach was found to be beneficial in other workplace intervention studies (Peper, Gibney, & Wilson, 2004; Pillastrini, et al., 2010). At end of intervention, participants were advised that the intervention program requiring daily use of the posture modification strategies had ended. They were now free to use the strategies at their own discretion.

**Standardisation of Interventions**

Interventions were delivered by two Occupational Therapists: One for the BF program and one for the ED program. The BF program intervention followed the
instructions included with the device. The ED program followed a pre-determined plan involving the elements previously listed, but modified at the time of each consultation to suit individual needs and preferences.

**Post-Intervention Use of Techniques**

Participants in both groups were advised that they could continue to use their interventions if they chose to do so during the follow-up period. The decision was made to include this in the research design in order to promote consistency between groups since ED group participants would be able to continue using their learned strategies during the follow-up period between T1 and T2.

**Conflict of Interest**

Since the primary researcher is the designer and proprietor of BackTone™, conflict of interest issues exist. These were addressed during design and implementation of the research project via oversight by the University of the Sunshine Coast and by supervisor scrutiny. Dr Janet Chaseling oversaw the design of the project and provided guidance on preliminary statistical analysis. The following methodological design strategies were implemented:

All T0, T1 and T2 data gathering was conducted by research assistants, except for two T2 events for which research assistants were unavailable. On those occasions, the primary researcher, accompanied by a tertiary-qualified film/video operator conducted the data gathering.

The biofeedback programs were delivered in accordance with the BackTone™ Instructions by the principal researcher; all education programs were delivered by a qualified and registered occupational therapist who was trained in the education protocols outlined on pages 40 - 41 and inexperienced with using the BackTone device personally or clinically.

Data extraction was conducted by the principal researcher and duplicated by a research assistant. Dr Aaron Wiegand provided guidance on mathematical considerations in relation to measuring in situ postural angles. The study supervisor
conducted preliminary statistical analyses which were completed in detail by the principle researcher.

**Ethics**

This study was approved by the Human Research Ethics Committee of the University of the Sunshine Coast on September 17, 2013 (ethics approval number S/13/544). The research was identified as low risk causing negligible threat or impact to participants. The ethics approval was modified on October 8, 2013 to include recruitment of participants from Sunshine Coast Council. It was further modified on March 7, 2014 to extend the data gathering period until July 2014 and to approve a change in proposed follow-up period from 6 weeks to 12 weeks. Written permission was gained from Sunshine Coast Council for their staff to participate in the project.

**Procedure for Extracting Data**

**Questionnaires**

Numerical Rating Scale (NRS) scores were measured directly from the 10cm scales using a ruler. Where the participant mark fell between whole numbers, it was measured to the nearest millimetre and the score entered to one decimal point. In this manner, scores were obtained for each participant at T0, T1 and T2 in the following categories:

- Pain in the neck, right shoulder, left shoulder, right elbow, left elbow, right wrist/hand, left wrist/hand, upper back, lower back and legs
- Self-assessed frequency of slouching
- Opinion about the strength of the relationship between posture and pain
- Opinion about their ability to change their own posture
- Opinion about their success in implementing the program strategies

**Video Imaging**

The primary postural parameters of interest for the study were the average in-task angles of the upper thoracic and cervical regions of the spine.
Sixteen continuous minutes of each video were selected. Where possible, this selection was based upon availability of uninterrupted computer-based activity. Still images were taken from the videos every two minutes for a total of nine images for each video. The activity in each image was examined. Usual computer-based work can involve different postural orientations, such as when reading a document on the desk surface, looking at the keyboard or looking at the computer screen. In order to compare like with like, posture while looking directly at the screen was chosen as the posture of interest. Only images of participants looking directly at the screen were included for initial analysis. Further detailed analysis identified additional images for rejection based on visibility of markers, movement of markers and camera position.

**Participant Postural Markers**

The following postural points were identified for each image: tragus of the ear, spinous process of C7 and a standardised thoracic point.

Initially the spinous process of T3 was identified and marked for the thoracic point. However, as noted previously, the marker sometimes moved in relation to the participant as their clothes wrinkled and slid over their body when they leaned forward and back again. An alternative means of identifying a thoracic point which would remain consistent across the three videos for each participant was required.

Ear-length was chosen as the unit of measurement because it would remain consistent in relation to other body parameters for each participant across the three videos. For each set of still images, an ear-length measurement was taken. A point on the outline of the upper back 1.5 ear-lengths from the C7 marker was found to be visible in most images and was noted to be a similar distance to T3 markers. It was selected as the thoracic point marker (ThM). The ThM was identified for every image (Figure 7).

A drawback of using the thoracic 1.5 ear-length mark is that potential increases in curve radius of the upper thoracic spine may cause variations to the position of the mark. However, variation in the distance along the upper back described by a change in the arc of the upper three thoracic vertebrae was thought to be minimal. It was also
considered to be less than variation caused by clothing movement. Future research may illuminate this issue.

Figure 7: Calculation of modified thoracic mark and spinal angles

The screen-based protractor BitRule (Charten Software 2007) was used to measure the angles between the screen horizontal at C7 and lines drawn between the markers. The raw cervical angle was formed by a line drawn between C7 and the tragus of the ear and the screen horizontal at C7. The raw thoracic angle was formed by a line drawn between C7 and the ThM and the screen horizontal at C7.

Adjustments for Potential Variations in Camera Position

Previously reported procedures for lateral marker imaging involve laboratory settings with standardised camera position, desk arrangement, chair setup and task performance. Sometimes plumb lines are positioned near the subject. Although the present study utilised standardised strategies for positioning the camera, there was potential for variations in camera angles between data gathering episodes given the variety of work locations and difficulties positioning the camera in certain work areas.
The following possible variations were identified and adjustment strategies were formulated.

**Camera rotation:** Rotation of the camera affects how the vertical line appears in an image. However, vertical lines in an image are parallel with other vertical lines at the same height. Suitable vertical environmental lines such as window frames were identified in each image. The on-screen protractor was used to measure the angle of that line to the screen horizontal, and raw cervical and thoracic angles were adjusted for any camera rotation.

**Distance from camera to participant:** Since the angles of cervical and upper thoracic spine were the parameters of interest, distance between camera and subject was irrelevant. The angle remains the same regardless of the distance.

**Camera tilt and slew:** Inclusion of a manubrium marker minimised camera slew since research assistants were required to position the camera so that both manubrium and C7 markers were visible in the camera screen at the same time.

Variance in camera tilt and slew was analysed by comparing variation in other stable anatomical landmark angles for each participant between data gathering time points. The angle formed by a line drawn along the longest axis of the ear and a line drawn from the lowest part of the ear to the tip of the nose (ear/nose angle) was identified as a standard angle, unlikely to change on the participant between data gathering episodes (Figure 8).

The ear/nose angle was measured for each participant at each data gathering episode. Ratios in the measured ear/nose angle between data gathering episodes were calculated by dividing the ear/nose angle at T0 by the ear/nose angles at T1 and T2. Mean ratios at T1 were 0.984 (SD = 0.026) for the BBF group and 0.989 (SD = 0.033) for the ED group. Mean ratios at T2 were 1.018 (SD = 0.023) for the BBF group and 1.004 (SD = 0.033) for the ED group. Image sets with ratios smaller than 0.95 and greater than 1.05 were rejected.
Summary of image inclusion/exclusion

Images were excluded for statistical analysis if:

- They did not show the participant working at the computer and looking directly at the screen.
- View of markers was completely obscured by clothes or hair.
- The marker position had moved and could not be adjusted on the screen. For example, if the marker was attached to a shirt collar, the shirt collar had moved away from the skin and could not be adjusted.
- The ratio of face angles between T0 and T1 or T2 was under 0.95 or over 1.05.
- Fewer than three images were available for measurement during each video.

Images were missing from T0 for one participant because the camera angle was too high and the C7 marker was unmeasurable. Images were missing from T1 for one participant because she was not available for the data gathering. Images were missing
from T2 for one participant because she declined to participate in the follow-up videoing. Missing values from these images were replaced based on group means where the participant’s other image scores fell within one SD from the group average. Three of the six missing values were replaced in this manner. For the remaining missing values, the corresponding scores from their pairs were deleted from the data set and treated as missing.

Two participants were excluded from statistical analysis because the face angle ratios were less than 0.95 at end of intervention and at follow-up.

A total of 716 suitable images were identified, with an average of 5.8 (SD = 2.2) images per participant video.

**Data Analysis**

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) software version 22. Data was first screened for missing values and outliers. Three raw pain scores were explained by participants as resulting from injuries due to sporting activity (two leg pain values) and a fall (neck injury with migraine). Those three scores were deleted and treated as missing data. Missing pain and opinion data were found to be missing in a random manner based on Little’s MCAR test. The missing data was replaced based on series means.

Data sets were examined for distribution qualities. The only raw score scale found to be normally distributed across all three data gathering episodes and within each treatment category was ‘self-assessed frequency of slouching’.

Pain in the neck, shoulders and upper back was the primary area of concern for this study and was required for participant inclusion in the study. In order to allow comparison between participants, combined neck, shoulder and upper back (NkShUB) pain variables were computed. Use of the SNQ body diagram promoted consistency by participants when rating their pain across these areas at different time points. The NkShUB variables were considered to provide an indication of pain for the upper body regions thought to be directly affected by upper body posture. The variables may allow some comparisons with other studies where neck, shoulder and upper back pain are computed and reported as a single value (Sandsjo, et al., 2010; Voerman, et al., 2007b).
Additional variables were computed to identify changes in pain scores for each of the body regions at end of intervention (T1) and follow-up (T2).

Outliers were examined using the outlier labelling rule with 2.2 as the multiplier as recommended by Hoaglin and Iglewicz (1987), and by visual review of histograms. Since most of the variable scales were non-normally distributed, outliers were defined when they satisfied both criteria of the outlier labelling rule and when they individually scored well above all other values. In this manner, eight outliers were identified from a total of 360 values, representing 2% of the scores. Outliers were Winzorised by replacing extreme values with the next consecutive value on the highest point of the variable scale not considered to be an outlier as described in Wilcox (2010).

Baseline data between the two groups was compared using the related-samples Wilcoxon signed rank tests for the ordinal scales, and the related-samples McNemar test for the nominal data (i.e. gender and employer) since most of the data was not normally distributed. Pearson correlation was used to explore associations between sample group rankings on subscales in order to explore the degree to which pairs were ranked.

Within-group improvements in posture and pain scores between T0 and T1 and between T0 and T2 were examined using the Wilcoxon signed rank test. Between-group differences in pain improvement scores were also examined using the Wilcoxon signed rank test. Between-group differences for improvements in spinal angles were examined using the Mann-Whitney U test.

Associations between opinions about posture and changes in posture and pain were explored using Pearson’s correlations. Chi-square analyses were applied to comparisons of the number of participants in each group who resolved their combined neck, shoulder and upper back pain at T1 and T2.

Two participants dropped out early and could not provide data at T1 or T2. One participant was found to have a pre-existing medical condition that excluded her from participating. All three participants and their pairs were excluded from data analysis and a per-protocol analysis was conducted.
4: RESULTS

Baseline Participant Characteristics

Fifty people volunteered for the project. Three were excluded because they did not meet inclusion criteria, and five were unable to meet the scheduling requirements of the study. Appointments were made for a research assistant to visit the remaining 42 participants at their workplace and conduct the baseline assessments.

Thirty-seven female and five male subjects (mean age = 44.5 years, SD = 9.59 years) participated in the study, with 21 participants in each group. Three pairs were excluded or withdrew part-way through the intervention program. One participant in the biofeedback group withdrew from the project after one week citing the reason: “I just can’t find the time to wear it and I don’t want to continue”. An additional biofeedback group participant withdrew from participating before commencing her wearing regime. A third participant revealed part-way through the intervention stage that, since the age of nine, she had suffered from an inflammatory-like, multi-site pain syndrome which doctors could not diagnose and which met exclusion criteria.

There were no differences between the dropout group and the remaining participants on any of the parameters at baseline, therefore it is likely that dropouts have not biased the results. The scores from all three participants who dropped out and their pairs were excluded from statistical analysis. Scores from the remaining 18 pairs of participants were considered for analysis. This number of participants exceeded the 14–15 pairs recommended by the power calculation.

At baseline, no significant differences were found between the two groups in terms of age, gender distribution, employer, body mass index, pain scores in any of the assessed body regions, self-assessed frequency of slouching, opinion regarding the impact of postural change on pain symptoms, self-assessed ability to change their own posture or postural spinal angles. Significant correlations were found between the two groups on baseline (T0) scores of neck pain ($r = 0.86$, p = 0.002), right shoulder pain ($r = 0.861$, p = 0.000) and left shoulder pain ($r = 0.551$, p = 0.018) indicating that the ranking order of the participants in the groups was suitable. Significant correlations were also found between neck pain and right shoulder pain ($r = 0.402$, p = 0.015) and
neck pain and left shoulder pain ($r = 0.355$, $p = 0.034$) across the whole group at baseline. Baseline data for the two groups is displayed in Table 1.

<table>
<thead>
<tr>
<th>Variables (RS score)</th>
<th>BBF (n = 18) (male n = 2)</th>
<th>ED (n = 18) (male n = 3)</th>
<th>Between Groups Difference</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean (SD)</td>
<td>n</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Age (years)</td>
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<td>18</td>
<td>47.2 (10.6)</td>
</tr>
<tr>
<td>BMI</td>
<td>18</td>
<td>26.1 (5.0)</td>
<td>18</td>
<td>25.2 (3.8)</td>
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<td>Neck</td>
<td>17</td>
<td>5.0 (2.5)</td>
<td>15</td>
<td>4.8 (2.8)</td>
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<tr>
<td>R. Shoulder</td>
<td>14</td>
<td>3.9 (2.9)</td>
<td>13</td>
<td>3.5 (3.1)</td>
</tr>
<tr>
<td>L. Shoulder</td>
<td>11</td>
<td>2.6 (2.8)</td>
<td>12</td>
<td>3.3 (2.8)</td>
</tr>
<tr>
<td>Upper Back</td>
<td>14</td>
<td>4.3 (3.1)</td>
<td>13</td>
<td>3.4 (2.7)</td>
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<tr>
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<td>3.6 (3.3)</td>
<td>16</td>
<td>3.4 (2.1)</td>
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<td>4</td>
<td>0.4 (1.1)</td>
</tr>
<tr>
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<td>0.5 (1.2)</td>
<td>3</td>
<td>0.6 (1.7)</td>
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<tr>
<td>R. Wrist/Hand</td>
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<td>5</td>
<td>0.6 (1.4)</td>
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<td>1.0 (1.7)</td>
<td>6</td>
<td>1.0 (1.9)</td>
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<td>Legs</td>
<td>8</td>
<td>1.4 (1.9)</td>
<td>8</td>
<td>1.3 (1.9)</td>
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<td>Self-Assessed Frequency of Slouching</td>
<td>18</td>
<td>7.3 (1.5)</td>
<td>18</td>
<td>6.7 (2.1)</td>
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<td>Assessment of Relationship between Posture and Pain</td>
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<td>7.9 (0.7)</td>
<td>18</td>
<td>7.3 (1.5)</td>
</tr>
<tr>
<td>Self-Assessed Ability to Change Posture</td>
<td>18</td>
<td>6.5 (2.5)</td>
<td>18</td>
<td>5.7 (2.5)</td>
</tr>
<tr>
<td>Upper Thoracic Angle (°)</td>
<td>16</td>
<td>56.97 (9.49)</td>
<td>16</td>
<td>54.43 (7.26)</td>
</tr>
<tr>
<td>Cervical Angle (°)</td>
<td>17</td>
<td>31.45 (9.31)</td>
<td>17</td>
<td>34.9 (8.49)</td>
</tr>
</tbody>
</table>

* Related-samples Wilcoxon signed rank test ($p \geq .05$ implies the groups are similar).

Table 1: Baseline Characteristics: Mean, Std Dev and p value of Sample Similarity
Pain Scores

Within Group Improvements

**Combined Neck, Shoulder & Upper Back Pain**

Both groups achieved significant improvements in average NkShUB pain at end of intervention (BBF p = 0.000; ED p = 0.002) and the improvements persisted at 12-week follow-up (BBF p = 0.000; ED p = 0.004).

**Neck Pain**

Both groups achieved significant improvements in average neck pain at end of intervention (BBF p = 0.002; ED p = 0.001) and the improvements persisted at 12-week follow-up (BBF p = 0.000; ED p = 0.012).

**All Body Regions**

At end of intervention the BBF group achieved significant improvements in average pain scores for seven of the ten body regions: neck (p = 0.002), right shoulder (p = 0.004), left shoulder (p = 0.034), upper back (p = 0.014), lower back (p = 0.004), left wrist/hand (p = 0.049) and legs (p = 0.049). The ED group achieved significant improvements in average pain scores for three of the ten body regions: neck (p = 0.001), left shoulder (p = 0.021) and lower back (p = 0.030). See Table 2 for results.

At 12-week follow-up, all the BBF group pain improvements except leg pain had persisted: neck (p = 0.000), right shoulder (p = 0.001), left shoulder (p = 0.045), upper back (p = 0.02), lower back (p = 0.004) and left wrist/hand (p = 0.046). At 12-week follow-up, ED group pain improvements were significant for two of the ten body regions: neck pain (p = 0.012) and right shoulder pain (p = 0.030). Improvement in lower back pain had diminished slightly, but was approaching significance (p = 0.052). Results are summarised in Table 2.

No significant differences were found in T1 or T2 within-group pain improvement scores for both elbows or right wrist/hand. Since only a small number of participants (between three and eight) in each group reported pain in the elbow, wrist/hand or legs, and given that the selection criteria and focus of this study were neck, shoulder and upper back pain, no further statistical procedures were applied to
scores relating to elbows, wrist/hand or leg pain. Low back pain scores were included in further statistical analyses because 12 participants for the BBF group and 16 participants for the ED group reported lower back pain. Significant improvement in lower back pain scores were found at both T1 (BBF and ED groups) and T2 (BBF group).

<table>
<thead>
<tr>
<th>Body Region</th>
<th>Group</th>
<th>Improvements at End of Intervention (T1)</th>
<th>Improvements at 12 Week Follow-Up (T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Improve-</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ment (NRS score)</td>
<td></td>
</tr>
<tr>
<td>Neck, Shoulders, Upper Back</td>
<td>BBF</td>
<td>10.0 (8.7)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>ED</td>
<td>5.4 (5.8)</td>
<td>0.002*</td>
</tr>
<tr>
<td>Neck</td>
<td>BBF</td>
<td>3.2 (3.1)</td>
<td>0.002*</td>
</tr>
<tr>
<td></td>
<td>ED</td>
<td>2.0 (2.2)</td>
<td>0.001*</td>
</tr>
<tr>
<td>Right Shoulder</td>
<td>BBF</td>
<td>2.9 (3.3)</td>
<td>0.004*</td>
</tr>
<tr>
<td></td>
<td>ED</td>
<td>1.1 (3.2)</td>
<td>0.201</td>
</tr>
<tr>
<td>Left Shoulder</td>
<td>BBF</td>
<td>1.6 (2.7)</td>
<td>0.034*</td>
</tr>
<tr>
<td></td>
<td>ED</td>
<td>1.8 (2.9)</td>
<td>0.021*</td>
</tr>
<tr>
<td>Upper Back</td>
<td>BBF</td>
<td>2.3 (3.4)</td>
<td>0.014*</td>
</tr>
<tr>
<td></td>
<td>ED</td>
<td>0.4 (2.4)</td>
<td>0.532</td>
</tr>
<tr>
<td>Lower Back</td>
<td>BBF</td>
<td>2.4 (3.0)</td>
<td>0.004*</td>
</tr>
<tr>
<td></td>
<td>ED</td>
<td>1.4 (2.4)</td>
<td>0.030*</td>
</tr>
<tr>
<td>Right Elbow</td>
<td>BBF</td>
<td>0.4 (1.6)</td>
<td>0.462</td>
</tr>
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<td></td>
<td>ED</td>
<td>0.3 (1.2)</td>
<td>0.6</td>
</tr>
<tr>
<td>Left Elbow</td>
<td>BBF</td>
<td>0.3 (0.9)</td>
<td>0.225</td>
</tr>
<tr>
<td></td>
<td>ED</td>
<td>0.3 (1.1)</td>
<td>0.599</td>
</tr>
<tr>
<td>R Wrist/Hand</td>
<td>BBF</td>
<td>1.2 (2.8)</td>
<td>0.161</td>
</tr>
<tr>
<td></td>
<td>ED</td>
<td>0.4 (1.0)</td>
<td>0.262</td>
</tr>
<tr>
<td>L Wrist/Hand</td>
<td>BBF</td>
<td>0.9 (1.8)</td>
<td>0.049*</td>
</tr>
<tr>
<td></td>
<td>ED</td>
<td>0.8 (1.8)</td>
<td>0.123</td>
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<tr>
<td>Legs</td>
<td>BBF</td>
<td>1.2 (2.1)</td>
<td>0.049*</td>
</tr>
<tr>
<td></td>
<td>ED</td>
<td>0.7 (1.8)</td>
<td>0.215</td>
</tr>
</tbody>
</table>

†Related-samples Wilcoxon Signed Rank Test.
*Indicates significant differences at p <0.05.

Table 2: Within Group Improvements in Mean Pain Score
Between Group Comparisons

**Combined Neck, Shoulder & Upper Back Pain**

At end of intervention, BBF group improvements were larger than ED group improvements for NkShUB pain (63% compared with 35.6%, \( p = 0.022 \)). At follow-up, the BBF group also achieved significantly larger improvements than the ED group improvements in NkShUB pain (78.1% compared with 40.3%, \( p = 0.048 \)).

At T1, three of the BBF group and none of the ED group had completely resolved their NkShUB pain. This difference approaches significance, \( X^2 (1, N=36) = 3.27, p = 0.07 \). At T2, eight of the BBF group and two of the ED group had completely resolved their NkShUB pain, and this difference was significant, \( X^2 (1, N=36) = 4.99, p = 0.026 \).

**Neck Pain**

At end of intervention, BBF group improvements were significantly larger than ED group improvements for neck pain (63.7% compared with 41.8%, \( p = 0.039 \)). At follow-up, the BBF group also achieved significantly larger improvements than the ED group improvements in neck pain (71.8% compared with 45.4%, \( p = 0.034 \)).

**All Body Regions**

At end of intervention, BBF group improvements were significantly larger than ED group improvements right shoulder pain (74% compared with 31.6%, \( p = 0.006 \)). There was also a trend for larger improvement in upper back pain (53.1% compared with 13.1%, \( p = 0.059 \)). At follow-up, the BBF group achieved significantly larger improvements than the ED group improvements in upper back pain (85% compared with 23%, \( p = 0.037 \)). Results for between group analyses in pain improvement are detailed in Table 3.

**Improvement between End of Intervention and Follow-Up**

A trend in increasing improvements between T1 and T2 average pain was observed for many of the body regions for both groups. However, only the BBF upper back pain improvement between T1 and T2 was significant (\( p = 0.016 \)). This means that
the BBF group upper back pain continued to improve after formal cessation of the intervention program.

<table>
<thead>
<tr>
<th>Body Region</th>
<th>T1 Average Improvement in Pain Scores</th>
<th>T2 Average Improvement in Pain Scores</th>
<th>Between Group Diff p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BBF Group Mean (SD)</td>
<td>ED Group Mean (SD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BBF Group Mean (SD)</td>
<td>ED Group Mean (SD)</td>
<td>Between Group Diff p value*</td>
</tr>
<tr>
<td>Neck</td>
<td>3.2 (3.1)</td>
<td>2.0 (2.2)</td>
<td>0.039</td>
</tr>
<tr>
<td>Neck, Shoulders, Upper Back</td>
<td>10.0 (8.7)</td>
<td>5.3 (5.8)</td>
<td>0.022</td>
</tr>
<tr>
<td>R. Shoulder</td>
<td>2.9 (3.3)</td>
<td>1.1 (3.2)</td>
<td>0.006</td>
</tr>
<tr>
<td>L. Shoulder</td>
<td>1.6 (2.7)</td>
<td>1.8 (2.9)</td>
<td>0.756</td>
</tr>
<tr>
<td>Upper Back</td>
<td>2.3 (3.4)</td>
<td>0.4 (2.4)</td>
<td>0.059</td>
</tr>
<tr>
<td>Lower Back</td>
<td>2.5 (3.0)</td>
<td>1.4 (2.4)</td>
<td>0.542</td>
</tr>
<tr>
<td>R. Elbow</td>
<td>0.4 (1.6)</td>
<td>0.3 (1.2)</td>
<td>†</td>
</tr>
<tr>
<td>L. Elbow</td>
<td>0.3 (0.9)</td>
<td>0.3 (1.1)</td>
<td>†</td>
</tr>
<tr>
<td>R. Wrist/Hand</td>
<td>1.2 (2.8)</td>
<td>0.4 (1.0)</td>
<td>†</td>
</tr>
<tr>
<td>L. Wrist/Hand</td>
<td>0.9 (1.8)</td>
<td>0.8 (1.8)</td>
<td>0.801</td>
</tr>
<tr>
<td>Legs</td>
<td>1.2 (2.1)</td>
<td>0.7 (1.9)</td>
<td>0.501</td>
</tr>
</tbody>
</table>

* Related-samples Wilcoxon Signed Rank Test
† No significant within group differences. Therefore, no between group comparisons could be made.

Table 3: Between Group Analyses of Improvements in Mean Pain scores

**Strength of Pain Outcomes**

All of the statistically significant improvements were greater than 33%. This means they could also be considered clinically important differences as recommended by Farra et al. (2001) and Salaffi et al. (2004).

Improvements in both neck pain and NkShUB for the ED group exceeded 33% at T1 and T2, indicating the improvements were clinically important and suggesting that both interventions were clinically robust. In the present study, the ED group represented ‘current clinical practice’ with which BackTone™ was compared.
Upper-Thoracic and Cervical Spinal Angles

**Within Group Improvements**

The BBF group achieved improvements in upper-thoracic and cervical spine angles at end of intervention ($p = 0.001$, $p = 0.02$) and the improvements persisted at follow-up ($p = 0.001$, $p = 0.006$). The ED group achieved improvement in upper-thoracic angle at end of intervention ($p = 0.001$), but the improvement did not persist at follow-up. There was no improvement in ED group cervical angles at end of intervention or at follow-up. See Table 4 for mean improvement scores.

**Between Group Comparison**

At end of intervention there was no difference between BF and ED group improvements in upper-thoracic angles but the BF group achieved significantly larger improvement in cervical angle ($p = 0.025$). At follow-up the BF group achieved significantly larger improvements than the ED group in both upper-thoracic ($p = 0.042$) and cervical angles ($p = 0.007$) (see Figures 9 - 12).

<table>
<thead>
<tr>
<th>Body Region</th>
<th>T1 Average Improvement in Spinal Angles</th>
<th>T2 Average Improvement in Spinal Angles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BBF Group Mean (SD)</td>
<td>ED Group Mean (SD)</td>
</tr>
<tr>
<td>Upper-Thoracic</td>
<td>7.74 (6.97)</td>
<td>5.03 (7.70)</td>
</tr>
<tr>
<td>Cervical</td>
<td>5.16 (6.13)</td>
<td>0.85 (5.01)</td>
</tr>
</tbody>
</table>

* Independent Samples Mann-Whitney U Test

Table 4: Spinal Angle Mean Improvement & Between Group Comparison
Figure 9: End of Intervention Improvement in Thoracic Angle

Figure 10: End of Intervention Improvement in Cervical Angle
Correlations between Pain and Posture

A significant moderate correlation was found between improvement in pain and improvement in cervical angle for the group as a whole at T2. For the BBF group, a significant strong correlation was found between improvement in thoracic angle and
improvement in pain at T1, but the correlation was no longer significant at T2. For the ED group, a significant strong correlation was found between improvement in cervical angle and improvement in pain at T1. See Table 5 for results.

<table>
<thead>
<tr>
<th></th>
<th>T1ImpThAng</th>
<th>T1ImpCvAng</th>
<th>T2ImpThAng</th>
<th>T2ImpCvAng</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correlations between</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvement in NkShUB &amp; Spinal Angles</td>
<td>.290</td>
<td>.170</td>
<td>.244</td>
<td>.342*</td>
</tr>
<tr>
<td>BBF Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correlations between</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvement in NkShUB &amp; Spinal Angles</td>
<td>.464*</td>
<td>.145</td>
<td>.251</td>
<td>.128</td>
</tr>
<tr>
<td>ED Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correlations between</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvement in NkShUB &amp; Spinal Angles</td>
<td>.088</td>
<td>-.020</td>
<td>.097</td>
<td>.487*</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (1-tailed).

Abbreviations: T1ImpThAng, improvement in thoracic angle at T1; T1ImpCvAng, improvement in cervical angle at T1; T2ImpThAng, improvement in thoracic angle at T2; T2ImpCvAng, improvement in cervical angle at T2

Table 5: Pearson’s correlations between improvement in neck, shoulder, upper back pain and improvement in spinal angles

Beliefs

Self-Assessed Frequency of Slouching

Since participants rated their posture by assessing the frequency of slouching, high self-assessed frequency of slouching (FofSl) scores indicated poorer self-assessed posture.

FofSl improved significantly between T0 (Mean = 7.02, SD = 1.83) and T1 (Mean = 4.43, SD = 1.89) for the whole group (p = 0.000) and this was maintained at T2 (Mean = 4.30, SD = 1.71, p = 0.000). Between group differences in improvements to FofSl were not significant at T1 (p = 0.862). However, the BBF group reported significantly larger improvement in FofSl at T2 (Mean = 3.69, SD = 2.16) than the ED group (Mean = 1.71, SD = 2.04, p = 0.010).
Comparison of Self-Assessed Frequency of Slouching with Postural Angles

For the group as a whole, there was a moderate negative correlation \( (r = -0.387, p = 0.026) \) between upper-thoracic angle and FofSl at T0; the correlation was strong at T1 \( (r = -0.401, p = 0.020) \) but negligible at T2. There were no significant correlations between FofSl and cervical angles.

Comparison of Self-Assessed Frequency of Slouching with Pain Scores

One moderate correlation was found between FofSl and upper body pain scores at baseline and at end of intervention. However at follow-up three strong correlations were found between FofSl and upper body pain scores suggesting that as participants gained persistent improvements in pain, there was a corresponding improvement in their self-assessed posture (Frequency of Slouching) (Table 6).

<table>
<thead>
<tr>
<th></th>
<th>Neck</th>
<th>Right Shoulder</th>
<th>Left Shoulder</th>
<th>Upper Back</th>
<th>Lower Back</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T0 Correlation between Self-Assessed Frequency of Slouching and:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.222</td>
<td>.219</td>
<td>.004</td>
<td>.374*</td>
<td>.073</td>
</tr>
<tr>
<td><strong>T1 Correlation between Self-Assessed Frequency of Slouching and:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.382*</td>
<td>.194</td>
<td>.102</td>
<td>.326</td>
<td>.105</td>
</tr>
<tr>
<td><strong>T2 Correlation between Self-Assessed Frequency of Slouching and:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.519†</td>
<td>.271</td>
<td>.331</td>
<td>.515†</td>
<td>.515†</td>
</tr>
</tbody>
</table>

† Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 6: Pearson’s Correlations between Self-Assessed Frequency of Slouching (Posture) and Pain Scores at T0, T1 and T2

Opinions Regarding Impact of Posture on Pain

For the group as a whole, no significant differences were found between participants’ opinions regarding the affect that posture has on pain between T0 (Mean = 7.5, SD = 1.3), T1 (Mean = 7.4, SD = 1.4) and T2 (Mean = 6.9, SD = 2.6). No within-group differences were found in opinions regarding the affect that posture has on pain between T0, T1 and T2.
For the group as a whole at T1, there was a moderate correlation that approached significance between improvement in NkShUB pain and participants’ beliefs about the relationship between posture and pain \( (r = 0.324, p = 0.058) \). This did not persist at T2.

No other significant correlations were found between participants’ opinions regarding the affect changing their posture has on pain and their actual improvements in neck, shoulder, upper back or lower back pain scores at T1 or T2 (Table 7).

<table>
<thead>
<tr>
<th></th>
<th>Improve-</th>
<th>Improve-</th>
<th>Improve-</th>
<th>Improve-</th>
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<tbody>
<tr>
<td></td>
<td>ment in</td>
<td>ment in</td>
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<td>ment in</td>
<td>ment in</td>
<td>ment in</td>
</tr>
<tr>
<td></td>
<td>NkShUB</td>
<td>Neck Pain</td>
<td>R. Shoulder Pain</td>
<td>L. Shoulder Pain</td>
<td>Upper Back Pain</td>
<td>Lower Back Pain</td>
</tr>
<tr>
<td>T1 Correlation</td>
<td>.324*</td>
<td>.252</td>
<td>.205</td>
<td>.178</td>
<td>.212</td>
<td>−.066</td>
</tr>
<tr>
<td>between Opinion re</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Difference to Pain</td>
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</tr>
<tr>
<td>and T1:</td>
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<td></td>
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</tr>
<tr>
<td>T2 Correlation</td>
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<td>.005</td>
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<td>.092</td>
<td>.141</td>
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<tr>
<td>and T2:</td>
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<td></td>
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</tr>
<tr>
<td>T1 Correlation</td>
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<td>.104</td>
<td>.260</td>
<td>.436**</td>
<td>.354*</td>
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<tr>
<td>Assessed Ability</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>to Change Posture</td>
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<td></td>
<td></td>
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<tr>
<td>and T1:</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>T2 Correlation</td>
<td>.341*</td>
<td>.279</td>
<td>.388*</td>
<td>.370*</td>
<td>−.009</td>
<td>.208</td>
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<td>Assessed Ability</td>
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<tr>
<td>to Change Posture</td>
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<tr>
<td>and T2:</td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 7: Pearson’s Correlations between Opinions re Difference to Pain, Self-Assessed Ability to Change Posture and Pain Scores at T1 and T2

Opinions Regarding Ability to Change Posture

For the group as a whole, participants’ opinions about their ability to change their posture increased between T0 (Mean = 6.1, SD = 2.5) and T1 (Mean = 7.5, SD =
1.4, p = 0.007) and the increase persisted at T2 (Mean = 7.4, SD = 1.8, p = 0.03). No
within-group differences were found in opinions regarding ability to change posture
between any time point except for the ED group at T2, where it increased from T0
(Mean = 5.69, SD = 2.47) to T2 (Mean = 6.88, SD = 1.46, p = 0.015).

Two strong correlations and one moderate correlation were found between
participants’ self-assessed ability to change their posture and actual improvements in
pain at T1. At T2, there were three moderate correlations between these variables
(Table 7). There were no significant correlations between participants’ self-assessed
ability to change their posture and actual improvements in postural angles.

**Intervention Fidelity**

**During Intervention Phase**

At end of intervention, the BBF group participants rated their success at
implementing the program strategies at 7.4 (SD = 1.7). The ED group participants rated
their success at implementing the program strategies at 6.3 (SD = 2.1). The difference
between these ratings approached significance (p = 0.052). Biofeedback group
participants wore their device an average of 40 times during the intervention program
(SD = 14.6).

**During Follow-Up Phase**

Seven of the 18 BF participants did not wear the device during the follow up
period. Six participants wore it fewer than 5 times and 4 wore it 10 - 12 times. One
participant wore the device twice daily for the follow-up period. BBF group
participants reported wearing their BackTone™ an average of 7.28 (SD = 13.8) times
altogether during the 12-week follow-up period. ED group participants reported that
they used the learned strategies on average 43.56 (SD = 42.51) times during the 12-
week follow-up period. Although the ED group reported use of techniques was larger
than the BBF group reported episodes of wearing during the follow-up period (p = 0.004), it is difficult to draw conclusions from this statistic because we have no
evidence about the similarity of the measures.
5: DISCUSSION

The aim of the present study was to compare the effectiveness of BBF with current posture education practice in reducing pain and improving upper body posture in computer users. The results indicate that both real-time, in-task BBF and ED reduced pain and improved posture in computer users. BBF was more effective than ED in reducing pain and the difference persisted over time. BBF improved both thoracic and cervical posture and the improvements persisted over time. ED improved thoracic posture only, but the improvement eroded over time. BBF was more effective than ED for improving cervical posture and the improvement persisted over time. BBF achieved similar results to ED for improving thoracic posture for the duration of the intervention program, however it was more effective than ED at achieving improved thoracic posture that persisted over time. Mean changes in postural angles ranged from -0.25° (SD 5.83°) for ED T2 cervical change to 7.74° (SD 6.79°) for BBF T1 upper-thoracic change. Standard Errors of Measurement for lateral marker imaging noted by Lau, et al., (2010) of 1.30 on the cervical angle and 1.00 on the upper thoracic angle should be taken into consideration when reviewing these findings.

The results advance earlier work which describes emerging evidence for postural improvement and pain reduction by using in-task, real-time BBF (Dean & Dean, 2006; Magnusson, et al., 2008; O'Sullivan, O'Sullivan, Campbell, O'Sullivan, & Dankaerts, 2012). Reasons for this difference between BBF and education can be hypothesised.

Each of our intervention groups achieved changes in their posture through different processes. Users of BBF did not have to remember to check and correct their posture, nor did they have to focus on the skill of adopting the target posture. They were able to attend to the work at hand and respond to the beep produced by the BBF device when it occurred. Although the beep may be considered distracting, it did not require a complex cognitive response. The response in itself guided postural correction because the only way to turn off the beep was to improve spinal angles. Consequently, there was no need to think about the skill of postural correction. Since the BBF alerted every time they slouched, participants performed their functional task utilising the
target posture throughout each training session. It is possible that by using these processes, BBF users became accustomed to what it felt like to perform their work task in the target posture rather than in a slouched posture.

ED group participants were taught the skill of adopting the target posture in stationary sitting and standing as well as dynamic sitting and standing under therapist supervision at their workplace. Reminder strategies were devised for each participant to provide cues to remember to check their posture and straighten up. Changing in-task posture for ED group participants involved initially acquiring the skill of adopting neutral posture and then incorporating that skill within other activities. To incorporate the neutral posture into other tasks, they had to remember to check their posture, make a decision about whether posture adjustment was required and implement the steps for postural correction. Changing postural behaviour for ED group participants required attention and memory.

BBF and ED groups accessed different types of feedback. In-task, real-time BBF provides augmented feedback in the form of ‘knowledge of performance’ (KP) to the user, allowing them to guide the execution of movement as it is occurring. This process differs from education-based strategies which provide ‘knowledge of results’ (KR) or outcomes to the user when they are reminded to check their posture.

As with studies by Farjad Sultan, Iohom and Shorten (2013), Cirstea (2007) and Levin and Mullineaux, Underwood, Shapiro and Hall (2012), the present study found the biofeedback that provides KP demonstrated greater effectiveness compared with biofeedback that provides KR for movement training. Farjad Sultan, Iohom and Shorten explored the use of different forms of feedback in training novice learners in ultrasound-guided interventional procedures. They divided 30 participants randomly between a control group (Group C) and two intervention groups. Group KP received feedback in the form of augmented error feedback (knowledge of performance), and Group KR received feedback at the end of each series of tasks (knowledge of results). They found that use of KP feedback resulted in fewer errors than use of KR feedback.

Cirstea and Levin (2007) compared the use of KP and KR feedback in training arm movements of 28 stroke survivors. Participants were randomly assigned to two
intervention groups which practised 10 sessions of 75 pointing movements. During practice, intervention groups received either faded (26.6% average) KP about arm joint movements or 20% KR about movement precision. A control group of non-disabled participants (n = 5) practised the same task with KR. They found that only KP produced motor recovery, whereas KR did not.

Mullineaux, Underwood, Shapiro and Hall (2012) explored the use of real-time biofeedback to improve accuracy of high-level rifle-shooters over bi-weekly training for four weeks. Real-time biofeedback regarding stance and shoulder stability was delivered with KP to the experimental group (n = 5) as they prepared for the shot. The control group (n = 4) were provided with shot accuracy information (KR). The biofeedback group showed meaningful improvements in performance and the control group showed no improvement.

Feedback guides us in performing a task and by doing so, strengthens our internal sensory awareness of how to perform that task. It is possible that real-time BBF, by providing information about how to move, is more effective in modifying the internal sensory awareness of how to perform the task at hand. For BBF participants, the task at hand was their computer work. For ED participants, the task at hand was divided between their computer work and postural monitoring. The process of postural modification for BBF group participants focused on changing the feeling of how to perform tasks such as working at the computer in neutral posture. Whereas the process of postural modification for ED group participants was that they learned the skill of posture checking/correcting and attempted to modify the manner in which they attended to a task so that their attention was diverted to their posture at regular intervals.

There is a difference between learning the skill of adopting upright neutral posture and incorporating that posture into habitual task performance. Our results highlight the challenge of using memory-based techniques to modify in-task habitual posture and suggest that real-time, in-task BBF changes the manner in which a task is performed, thereby changing the expressed posture. With these considerations in mind, the nature or definition of habitual in-task posture becomes much more related
to how a task is performed. We could consider that habitual in-task posture is the relationship between body parts that an individual adopts while performing a task at a given time.

**Intensity of Therapist Contact and Education Interventions**

In this present study, ED participants improved thoracic angle at end of intervention, but the improvement was no longer present at follow-up. Pillastrini et al. (2010) and Jaromi et al. (2012) described education-based programs that measure spinal posture and reported success at maintaining postural improvements over the long term, but they relate to low back pain, involve intensive intervention and neither used in-task measurement of spinal angles.

Pillastrini et al. (2010) investigated the effectiveness of a comprehensive on-site program for work-related posture and low back pain in video display terminal workers. They compared a program which involved ergonomic intervention, postural training, fortnightly follow-ups for six months, supply of ergonomic equipment and provision of an informative brochure, with the provision of the informative brochure alone. They used the Rapid Entire Body Assessment to indicate postural risk and a pain drawing to measure point prevalence of low back pain. Data was collected at baseline, at end of intervention, and at 6, 12, 30 and 36 months. Improvements were found in low back pain prevalence and whole body postural risk for the intervention group at end of intervention and at all follow-ups. Pillastrini et al.’s. study provides evidence for the benefit of using an intensive intervention education-based program in reducing incidence of low back pain, but in-task spinal posture cannot be determined. Jaromi et al. (2012) also reported long-term postural change using an intensive six-week program of exercise and education. However, as previously discussed, they did not measure in-task, real-life posture. Inferences may be considered in relation to the extent of program contact in these studies and the persistence of benefits over time.

In our study, there was less intensive intervention and the postural changes achieved by education strategies did not persist over time. The ED group demonstrated skill in achieving thoracic angle improvements at end of intervention, but they did not consistently incorporate those changes into habitual behaviour that
was sustained over the longer term. An education approach to changing posture may require much greater input in terms of therapist contact, duration and program intensity than a BBF program to produce long-term change.

**ED Changes in Pain**

In our study, pain improvements that the ED group had achieved at end of intervention persisted at follow-up despite fading of improved thoracic spinal angle. It is possible that although the ED group had not changed habitual posture at T2, they were correcting their posture at critical times or with enough frequency to affect their pain. It is also possible that it may take longer than 12 weeks for their deteriorated posture to have an impact on their pain.

**Participant Beliefs about Posture**

Both groups’ rating of their posture improved by end of intervention and at follow-up. However, the BBF improvement in self-rated posture was larger than the ED group at follow-up. For the BBF group, this is consistent with postural and pain outcomes. ED group self-assessed posture had improved by follow-up, even though improvements in their actual postural angles had diminished.

Correlations between self-ratings of posture and actual posture angles were mixed. There appeared to be more correlations between self-assessed posture and pain than there were between self-assessed posture and measured spinal angles. Opinions about the effect that improved posture has on pain correlated moderately with changes in pain at T1, but not at T2. Opinions about ability to change posture correlated strongly with changes in pain at T1 and moderately at T2.

Participants’ self-assessment of their posture and their ability to change their posture appeared to correlate with changes in pain rather than objective posture. This finding raises questions about how accurate people are in their understanding of their own postural behaviour. The findings imply that it is difficult to formulate an accurate awareness of our own in-task habitual posture and the experience of pain provides anchors against which we can evaluate posture. Use of NRS to evaluate one’s own posture is not supported.
Postural Training as part of a Comprehensive Program

This research focused purely on targeted posture retraining without including additional strategies such as exercise or ergonomic training and modification. The reason for this design was to examine techniques which may then be included as part of a comprehensive program. Existing work supports the application of multifaceted programs for reducing musculoskeletal disorders. However, research around multifaceted programs may not allow us to compare individual modalities for achieving a particular component of the program. For example, we may wish to identify the most appropriate way to train posture in a given situation or the most appropriate exercise program. Examination of individual therapeutic strategies may allow us to put together a more effective comprehensive approach for specific situations.

Comparative Cost of Implementing the Interventions

For the BBF group, short-term and long-term improvements in posture were achieved with two 45-minute workplace interventions by a therapist as well as the wearing regime of the participants. However for the ED group, two 45-minute workplace interventions by a therapist as well as the ED regime achieved short-term postural gains which eroded over time. Furthermore, the pain improvements achieved in the BBF group were significantly larger than those achieved by the ED group.

Long-term changes achieved in the study by Pillastrini et al. (2010) which utilised education-based posture interventions, involved two workplace visits followed by six months of fortnightly workplace follow-ups. The Jaromi et al. (2012) study which used education-based techniques involved six 50-minute sessions. This is consistent with the implied need for longer-term review when using education-based strategies in our study.

If findings from Pillastrini (2010) and Jaromi (2012), are extrapolated it may be considered that the ED group could achieve similar outcomes with longer and more complex interventions.
Limitations of the study

Although the ranking, pairing and group allocation process was conducted by a researcher blinded to participant identity, it was impossible to blind participants to their intervention type. It was also not possible to blind research assistants to the intervention type during data gathering since questionnaires varied slightly according to the intervention. It is possible that research assistants may have been biased towards more positive results for either intervention, however use of quantitative scales may have minimised this effect. Blinding of data gatherers may be included in future research by using additional researchers to gather intervention-specific outcome information.

Two of the 20 BBF participants either dropped out at commencement or part-way through the intervention. Sandsjro et al. (2010) reported that 11 of their 33 EMG biofeedback group dropped out. Voerman et al. (2007) reported that 5 of their 42 EMG biofeedback group dropped out before end of intervention and 4 dropped out before first follow-up. Ma et al. reported that 5 of their 15 EMG biofeedback group dropped out at or before the end of intervention. The dropout rate in our study is comparable or lower than these similar studies involving wearable biofeedback devices.

Drop-outs did not differ in any of the measured parameters from those fulfilling the intervention. Therefore, it was considered that their omission did not affect the outcome of the research.

Missing image data resulted in 15 pairs available for within group statistical analysis for spinal angles. This was considered acceptable, since it exceeded the 10 pairs recommended by the power calculation. Improved imaging strategies may reduce the incidence of missing image data in future studies.

Detailed recording of use of interventions during the follow-up period was not conducted as it was felt that the process of recording may affect behaviour. Consequently the data regarding frequency of use of interventions during the follow-up period was a retrospective estimation by participants. However the process by which participants achieve modification to their postural behaviour may have been illuminated by gathering this type of data.
Data regarding participant access to other interventions for their musculoskeletal pain was not collected. Since other interventions may affect their pain scores, this represents a potentially confounding factor. Future research should include collection of other treatments accessed by participants.

The current project used a 12-week follow-up period in line with other research. However, it is possible that the disparity between ED T2 pain and posture outcomes may change with longer follow-up. A longer follow-up period may have helped to clarify.

This study focused on seated posture and only measured seated posture as an outcome. Therefore we are unable to make inferences about overflow of the training to other activities.

Generalizability

Outcomes for this study were primarily focused on seated, computer-based work. Care should be taken when generalising the findings to situations involving upright posture or to posture during dynamic tasks such as manual handling.

Implications for Research

Given the improvements in posture achieved during the study, follow-up after 1–2 years may provide some useful information regarding the potential of postural change to reduce incidence MSDNUL in computer users.

The study reported here demonstrated positive benefits for using BBF over ED to reduce pain and retrain posture in computer users. Posture retraining forms one strategy of a comprehensive program for addressing MSDNUL. Multifaceted programs which include BBF as the posture retraining modality should be explored to see if they lead to reduced risk and improved outcomes for MSDNUL in the longer term.

Participants in the BF group were asked how frequently they wore their device, but they were not asked about implementation of postural correction strategies during the follow up period. This was because the focus of the BF strategy was to modify the manner in which participants habitually worked at the computer; they were not asked to monitor their posture or to remember to straighten up since those strategies
formed a major component of the ED approach. However it may be useful to explore the personal processes and strategies utilized by participants who achieved greater changes in postural angles in order to inform future research and practice.

Given the focus of this study on MSDNUL in computer users, seated computer work was chosen as the posture to be targeted and measured. However, postural BBF may also be applied to other dynamic tasks with beneficial outcomes. Exploration of the potential for using BBF in other situations is warranted, such as in dentistry or nursing where high rates of MSD are reported (Bernal et al., 2014; Hayes, Cockrell, & Smith, 2009). The physically complex nature of tasks in these professions may require adoption of different protocols.

Our preliminary results relating to opinions about posture imply that people’s awareness of and understanding about posture is complex. Further qualitative research about how people think and feel about posture would help to identify themes for further investigation.

In research relating to posture, the nature of the postural behaviour under scrutiny should be clearly defined. The appropriateness of the outcome measure in relation to the posture under scrutiny can then be considered. For example one-off measurements of participants in an experimental or clinical environment may not necessarily reflect real-life, habitual, in-task posture. Clarification of the postural behaviour under scrutiny would enable researchers to fit their knowledge into a broader discussion and understanding of the nature of postural behaviour.

Numerical Rating Scales have been used in a number of studies relating to posture and MSDNUL. NRS are used in clinical practice and are easy to replicate. They demonstrate suitable validity and reliability for use both in research and clinical practice and are acceptable for statistical analysis. However, data relating to actual NRS scores is frequently not reported. If NRS scales were used more widely in research and the score data was reported, some comparison between studies may be facilitated.

The use of in-task, lateral marker imaging appears to be a useful tool for measuring some aspects of posture. Although applying this strategy is time consuming, it can provide valuable information. The score adjustment procedures developed in
this study may be useful for workplace-based research, but further validation would be valuable. Further research is recommended in order to standardise strategies and to provide reliability and validity data.

**Implications for Clinical Practice**

Clinicians attempt to retrain habitual posture in order to enhance and maintain pain reductions achieved with treatment and to prevent recurrence of problems. However, education alone as a strategy for retraining habitual posture does not consistently achieve lasting change; therefore clients may be placed at risk of recurrence. Consideration should be given to including real-time BBF as part of a posture education program, since this study found it achieved improved pain and posture that lasted over time.

**Compliance**

Clinicians would need to explore the likelihood of client compliance in wearing the biofeedback device when considering its inclusion in a treatment program. Clients who take on the device, but don’t wear it may potentially experience a sense of failure. Although a similar sense of failure is also potentially possible with clients who undertake an education program but are unable to achieve change to their habitual posture, the effect for each client should be considered.

**Practical Resources**

Clinicians using an Education Approach may do so with very limited resources. However those using a Biofeedback approach need to gain access to the device. Improved posture is not simply a skill which, once acquired, will be incorporated into task performance given the application of sufficient memory and concentration. The acquisition of changed habitual posture is a task-related phenomenon consistent with the proposition by Krakauer, Mazzoni, Ghazizadeh, Ravindran and Shadmehr (2006) that the history of implicitly remembered contexts in which training occurred affects generalisation of motor learning.

BBF and posture education should form part of a suite of modalities for dealing with problems related to MSDNUL, as many of those modalities facilitate maintenance
of improved postures by reducing disparities between task demand and performance capability.

**Conclusions**

The aim of the present study was to compare the effectiveness of BBF with current posture education practice in improving upper body posture and reducing pain in computer users. The results indicate that BBF achieves significant improvements in posture and pain, and is more effective than current practice in retraining upper body posture and reducing pain. This most likely reflects the nature of the mechanisms by which biofeedback works and the fact that it allows for training while performing the task of interest.

Clinicians should consider including BBF in posture education programs. Further research should explore processes by which postural behaviour is expressed in real-life, activity-based situations.
6: REFERENCES


7: APPENDICES
## Appendix A: Posture Study Screening Tool

Name: ______________________  Email: _____________________________

Telephone: _____________________  Work Location (Room Number): ________

<table>
<thead>
<tr>
<th>Construct</th>
<th>Question</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic demographics</td>
<td>How old are you?</td>
<td>______ Years</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>Male / Female / Intersex or other</td>
</tr>
<tr>
<td>Working hours</td>
<td>How many hours do you work per week?</td>
<td>□ 20 or more  □ Less than 20</td>
</tr>
<tr>
<td></td>
<td>Do you use the computer every working day?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>Neck/shoulder/Upper back pain</td>
<td>Have you experienced neck, shoulder or upper back pain in the past 7 days?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td></td>
<td>Have you experienced neck, shoulder or upper back pain on at least 30 days (not necessarily consecutively) in the past 12 months?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>Medical history</td>
<td>Have you been diagnosed with any inflammatory diseases? (e.g., rheumatoid arthritis, scleroderma)</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td></td>
<td>Have you been diagnosed with any neurological problems?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td></td>
<td>Do you have any conditions that may cause numbness or swelling of the joints (pregnancy, heart condition and arthritis)</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td></td>
<td>Do you experience pain as a result of any orthopaedic injuries to your back, neck, shoulders or arms? (e.g. fractures or sprains caused by accidents)</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td></td>
<td>Details:</td>
<td>____________________________</td>
</tr>
</tbody>
</table>

If included:  Participant Code: ________
Appendix B: Participant Information Sheet for Postural Biofeedback Study

**Project Title:** The use of biomechanical biofeedback to retrain posture and reduce symptoms of musculoskeletal disorders in computer users

**Investigators**

Lorraine Josey (Masters Candidate)  
Dr Kieran Broome (Supervisor)

*We would like to invite you to take part in a study.*

*What is the Study About?*

Many computer users experience neck, shoulder or upper back pain and posture is widely acknowledged to be one of the contributing factors. The purpose of this study is to evaluate whether we can retrain posture using biofeedback (BackTone™) or Postural Retraining and to see if doing so results in reduced symptoms of neck, shoulder and upper back discomfort.

**What will I have to do?**

Participation in the following study is voluntary. You may withdraw at any stage, without explanation and there will be no consequences as a result.

A short interview, about your health and posture will take place at your worksite. The interview will take 10 to 15 minutes. After that we will video your posture whilst you go about your normal work for 16 minutes. We will use a small camera, mounted on a tripod nearby and we will attach 1.2cm markers to your ear, neck, shoulder and back.

You will then be provided with either a biofeedback trainer (‘BackTone’) which consists of a small electronic unit held in place by a light webbing brace and worn over your clothes for short periods during your daily routine, or two on-site postural training/education sessions.

We will visit you again to complete questionnaires and video your working posture after three weeks and nine weeks. We expect each of the three data gathering visits to take about 35 minutes. Of that time, you will be going about your normal work for 16 minutes. We will also visit you for 2 x 20 minute sessions to fit your biofeedback and check on it, or to provide the postural training sessions.
What happens after that?
- We will take the information and prepare reports that we will be able to share with people interested in this topic.
- We can give you a copy of the reports or a summary, if you like. If you would like a copy, please inform the Principal Researcher during your initial interview and supply contact details.

Everything will be kept confidential
- All information you give us will be stored securely.
- Video data will be de-identified and stored securely for 5 years, after which it will be deleted.
- When we write the reports, your identity will not be revealed.

What are the risks and benefits of taking part in this research?
- You may feel uncomfortable about being videoed and completing questionnaires in your place of work.
- You may feel uncomfortable about wearing your biofeedback device at work and at home, or applying the posture correction strategies in your workplace.
- There may be potential to aggravate your symptoms if you do not use the device as recommended (e.g. wearing it for very long periods).
- There may be a benefit to you in that you will receive training in re-educating your posture.
- If you have any concerns or queries, please contact the project team.

What if I do not want to be involved?
- That’s fine. It is completely up to you.
- You are free to refuse to answer any questions.
- You can decline any measurements being taken.
- You can stop participating in the project at any time.

Who has approved this study?
This study has been reviewed and approved by the ethics committee at the University of the Sunshine Coast.

What if I have more questions?
- Please ask us for more information: Lorraine Josey on (07) 54766715 or email LKJ006@student.usc.edu.au
- If you would like to speak to someone at the University not directly involved with the study, you may telephone the Secretary, Human Research Ethics Committee on (07) 5459 4574.

If you have any complaints about the way this research project is being conducted you can raise them with the Principal Researcher or, if you prefer an independent person, contact the
Chairperson of the Human Research Ethics Committee at the University of the Sunshine Coast: (c/-the Research Ethics Officer, Office of Research, University of the Sunshine Coast, Maroochydore DC 4558; telephone (07) 5459 4574; facsimile (07) 5430 1177; email humanethics@usc.edu.au).

The researchers and the University of the Sunshine Coast thank you for your time taking part in this study.

Lorraine Josey
Masters Candidate
Appendix C: Participants Consent Form for Postural Biofeedback Study

Participant Code: ______

Title of Study: The use of biomechanical biofeedback to retrain posture and reduce symptoms of musculoskeletal disorders in computer users (ethics approval number S/13/544)

Investigators:

1. Lorraine Josey, Occupational Therapist, HDR Student, School of Health and Sport Sciences, University of the Sunshine Coast (Principal Researcher).
2. Dr Kieran Broome, Occupational Therapist, School of Health and Sport Sciences, University of the Sunshine Coast
3. Professor Marion Gray, Occupational Therapy, School of Health and Sport Sciences, University of the Sunshine Coast

I, ________________________________ (Please print), agree to take part in the research project titled, “The use of biomechanical biofeedback to retrain posture and reduce symptoms of musculoskeletal disorders in computer users”.

- I have read, understood and kept a copy of the Participant Information Sheet for the above research project.
- I freely consent to my participation.
- I understand that this research project will be carried out as described in the Participant Information Sheet. I know it will involve:
  - Three interviews, each of up to 45 minute duration at my worksite.
  - Video imaging of myself working at my computer during each interview
  - Participation in a postural retraining program as outlined in the Participant Information Sheet.
- I understand that my privacy will be maintained at all times. Nobody will be able to identify me in any report about this study.
- I understand that I am free to decline to answer a question, decline from participating in any measurements, or to withdraw from this project at any time.
- I give consent for data about my participation to be used in a confidential manner for the purposes of this research project, and in future research projects.

My signature: ____________________________  Date:__________
Appendix D: Symptom Checklist – (commencement, end of program, and at follow up)
Appendix E: Initial Interview Questionnaire (completed by all participants)

Participant Code: _______

1. Can you describe your current posture habits? __________________________________________

__________________________________________________________________________________

__________________________________________________________________________________

__________________________________________________________________________________

2. How often do you slouch or stoop? Make a mark on the line to indicate.

[ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ]

Virtually never  All the time

3. What difference will changing posture make to your pain or discomfort? Make a mark on the line to indicate.

[ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ]

No difference at all  My pain will go

4. How effective are you at changing your posture habit? Make a mark on the line to indicate.

[ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ]

I can’t change my posture  I am able to change my posture

5. What is your height (in cm) _______

6. What is your weight (in kg) _______
Appendix F: End Interview Questionnaire BF (completed by BBF group)

Participant Code: ______

1. How well were you able to implement the wearing regime for your BackTone?

[Varying scale from No success to I was completely successful]

2. On average, how many days per week were you able to wear your BackTone? (Please circle)

0 1 2 3 4 5 6 7

3. On the days you wore your BackTone, how many times did you wear it? ______

4. What activities or tasks were you doing when you wore your BackTone? ______

5. Can you describe your current posture habits? ________________________________

6. How often do you currently slouch or stoop? Make a mark on the line to indicate.

[Varying scale from Virtually never to All the time]

7. What difference does changing posture make to your pain or discomfort? Make a mark on the line to indicate.

[Varying scale from No difference at all to My pain will go]

8. How effective are you at changing your posture habit? Make a mark on the line to indicate.

[Varying scale from I can’t change my posture to I am able to change my posture]

9. Do you have any comments or suggestions regarding the posture training program? ___

_______________________________________________________________________________

_______________________________________________________________________________
Appendix G: End Interview Questionnaire ED (completed by ED group)

Participant Code: ________

1. How well were you able to implement the strategies for changing your posture?
   
   Not at all ___________  All the time ___________

2. Can you describe your current posture habits? __________________________
   __________________________
   __________________________

3. How often do you slouch or stoop? Make a mark on the line to indicate.
   
   Virtually never ___________  All the time ___________

4. What difference will changing posture make to your pain or discomfort? Make a mark on the line to indicate.
   
   No difference at all ___________  My pain will go ___________

5. How effective are you at changing your posture habit? Make a mark on the line to indicate.
   
   I can’t change my posture ___________  I am able to change my posture ___________

6. Do you have any comments or suggestions regarding the posture training program? ____
   __________________________
   __________________________
   __________________________
   __________________________
Appendix H: Follow-Up Interview Questionnaire *(completed by BBF group)*

Participant Code: ________

1. Can you describe your current posture habits? ____________________________

2. Have you worn your BackTone since our last meeting? Yes/No

3. If Yes, how many times? ____________________________

4. How often do you slouch or stoop? Make a mark on the line to indicate.

   [Virtually never] [All the time]

5. What difference will changing posture make to your pain or discomfort? Make a mark on the line to indicate.

   [No difference at all] [My pain will go]

6. How effective are you at changing your posture habit? Make a mark on the line to indicate.

   [I can't change my posture] [I am able to change my posture]

7. Do you have any comments or suggestions regarding the posture training program? ____

   ____________________________

   ____________________________

   ____________________________

   ____________________________
Appendix I: Follow-Up Interview Questionnaire *(completed by ED group)*

Participant Code: _______

1. Can you describe your current posture habits? ________________________________

2. Have you used any techniques you learned in our program since our last meeting?
   Yes/No

3. If Yes, which techniques did you use? ________________________________

4. If you answered Yes in Q.2, how often did you use the technique? ________________

5. How often do you slouch or stoop? Make a mark on the line to indicate.

   [Virtually never] [All the time]

6. What difference will changing posture make to your pain or discomfort? Make a mark on
   the line to indicate.

   [No difference at all] [My pain will go]

7. How effective are you at changing your posture habit? Make a mark on the line to indicate.

   [I can’t change my posture] [I am able to change my posture]

8. Do you have any comments or suggestions regarding the posture training program? ____

   ____________________________________________________________
## Appendix J: Wearing Diary

<table>
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<tr>
<th></th>
<th>Week 1</th>
<th></th>
<th>Week 2</th>
<th></th>
<th>Week 3</th>
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<td>Day 1</td>
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<td>Day 1</td>
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<tr>
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<td>Day 7</td>
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<td>Day 7</td>
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<td>Day 7</td>
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</tbody>
</table>

Please record the approximate number of minutes for each time you wore your BackTone on each day.

Participant code: [Signature]
Appendix K: Recruitment Email – sent to staff following permission from Department Heads

Participant: Using Biofeedback and Education to Retrain Posture and Reduce Discomfort.

You are invited to participate in a study investigating the use of education and biofeedback to retrain posture and reduce discomfort. The study is being undertaken as part of a Master of Philosophy degree.

Who can participate?

Regular computer users aged between 18 and 60 years who work 20 hours or more per week are invited to participate in the study. Participants will be excluded if they have neurological deficits, inflammatory disease, pain due to orthopedic injury or conditions that may cause numbness or swelling of the joints (pregnancy, heart condition).

What does it involve?

You will be invited to wear a small biofeedback device (BackTone) for short periods during your daily routine or you will receive two individualised, on-site postural education sessions.

You will also be invited to complete some short questionnaires and we will take video of your posture whilst you are doing your usual work.

Please take your time to think about whether you wish to participate.

If you are interested in participating or would like to know more information, please email Lorraine Josey at LKJ006@student.usc.edu.au

Research Team:

Lorraine Josey, Masters Candidate, School of Health and Sport Sciences, University of the Sunshine Coast (Principal Researcher).

Dr Kieran Broome, Occupational Therapist, School of Health and Sport Sciences, University of the Sunshine Coast

Professor Marion Gray, Occupational Therapy, School of Health and Sport Sciences, University of the Sunshine Coast

The University of the Sunshine Coast and Researchers for this project wish to thank you for your interest and/or involvement in the project.
Appendix L: Announcement in Staff Newsletter (Sunshine Coast Council)

Do you want to change your posture?

Council is working with the University of the Sunshine Coast (USC) to compare ways to retrain posture and reduce pain (LINK TO FLYER WITH INFORMATION FROM RECRUITMENT EMAIL – appendix L). USC are looking for office-based employees who would like to participate in the study. If you currently use a computer every work day, and experience some discomfort in your neck, upper back, shoulder or arm then you may benefit from participating. If you are interested or would like more information, please contact Lorraine Josey at LKJ006@student.usc.edu.au or ph: 5476 6715 / 0403 279 396.
Appendix M: Handout about Posture and Workstation Setup, page 1 & 2

Steps for Adopting Good Posture

*In Standing (feet slightly apart)*

1. Lift your sternum (breastbone) straight up towards the ceiling.

2. Imagine a string attached to the crown (back) of your head and lift yourself up where the string is attached.

3. Pull your tummy in slightly (about one tenth of a contraction). Do not pull it in hard - you will not be able to maintain that amount of work.

4. Check your shoulders are relaxed and level. Do not pull your shoulders back or lift them up.

5. Check that your neck is relaxed - not held rigidly in place. Imagine your head as a ball balanced on top of your neck - do not strain to hold your head in position.

6. Check that your knees are relaxed.

*In Sitting*

1. Sit with your bottom as far back in the seat as possible.

2. Place your feet flat on the floor.

3. Lift your breast bone (sternum), bringing your upper back against the chair.

4. Imagine a string attached to the crown of your head and lift yourself up where the string is attached.

5. Pull your tummy in slightly.

6. Check that your shoulders are relaxed. Do not pull your shoulders back or lift them up. Do not allow your shoulders to roll forward.
# Appendix N: CONSORT NPC Extension Checklist

## Checklist of Items for Reporting Trials of Nonpharmacologic Treatments*

<table>
<thead>
<tr>
<th>Section</th>
<th>Item</th>
<th>Standard CONSORT Description</th>
<th>Extension for Nonpharmacologic Trials</th>
<th>Reported on Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title and abstract†</strong></td>
<td>1</td>
<td>How participants were allocated to interventions (e.g., “random allocation,” “randomized,” or “randomly assigned”)</td>
<td>In the abstract, description of the experimental treatment, comparator, care providers, centres, and blinding status</td>
<td>i - iii</td>
</tr>
<tr>
<td><strong>Introduction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Background</td>
<td>2</td>
<td>Scientific background and explanation of rationale</td>
<td></td>
<td>Pp 1 - 26</td>
</tr>
<tr>
<td><strong>Methods</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participants†</td>
<td>3</td>
<td>Eligibility criteria for participants and the settings and locations where the data were collected</td>
<td>When applicable, eligibility criteria for centres and those performing the interventions</td>
<td>P 31 - 32</td>
</tr>
<tr>
<td>Interventions†</td>
<td>4</td>
<td>Precise details of the interventions intended for each group and how and when they were actually administered</td>
<td>Precise details of both the experimental treatment and comparator</td>
<td>P 38 - 41</td>
</tr>
<tr>
<td></td>
<td>4A</td>
<td>Description of the different components of the interventions and, when applicable, descriptions of the procedure for tailoring the interventions to individual participants</td>
<td></td>
<td>P 38 - 41</td>
</tr>
<tr>
<td></td>
<td>4B</td>
<td>Details of how the interventions were standardized</td>
<td></td>
<td>P 41</td>
</tr>
<tr>
<td></td>
<td>4C</td>
<td>Details of how adherence of care providers with the protocol was assessed or enhanced</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>5</td>
<td>Specific objectives and hypotheses</td>
<td></td>
<td>P 26-27</td>
</tr>
<tr>
<td><strong>Outcomes</strong></td>
<td>6</td>
<td>Clearly defined primary and secondary outcome measures and, when applicable, any methods used to enhance the quality of measurements (e.g., multiple observations, training of assessors)</td>
<td></td>
<td>P 33 - 36</td>
</tr>
<tr>
<td>Topic</td>
<td>Question</td>
<td>Page</td>
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<tr>
<td>------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
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<tr>
<td>Sample size†</td>
<td>How sample size was determined and, when applicable, explanation of any interim analyses and stopping rules</td>
<td>31</td>
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<tr>
<td>Randomization–sequence generation†</td>
<td>Method used to generate the random allocation sequence, including details of any restriction (e.g., blocking, stratification)</td>
<td>36–37</td>
<td></td>
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<tr>
<td>Allocation concealment</td>
<td>Method used to implement the random allocation sequence (e.g., numbered containers or central telephone), clarifying whether the sequence was concealed until interventions were assigned</td>
<td>37</td>
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<tr>
<td>Implementation</td>
<td>Who generated the allocation sequence, who enrolled participants, and who assigned participants to their groups</td>
<td>32,37</td>
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<tr>
<td>Blinding (masking)†</td>
<td>Whether or not participants, those administering the interventions, and those assessing the outcomes were blinded to group assignment</td>
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<tr>
<td>Statistical methods†</td>
<td>Statistical methods used to compare groups for primary outcome(s); methods for additional analyses, such as subgroup analyses and adjusted analyses</td>
<td>48–49</td>
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## Results

<table>
<thead>
<tr>
<th>Item</th>
<th>Page</th>
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<tbody>
<tr>
<td>Participant flow†</td>
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<tr>
<td>Flow of participants through each stage</td>
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<tr>
<td>(a diagram is strongly recommended)</td>
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<tr>
<td>---specifically, for each group, report</td>
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<tr>
<td>the numbers of participants randomly</td>
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<td>assigned, receiving intended</td>
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<td>treatment, completing the study</td>
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<td>protocol, and analyzed for the</td>
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<tr>
<td>primary outcome; describe</td>
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<tr>
<td>deviations from study as planned, together</td>
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<tr>
<td>with reasons</td>
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<tr>
<td>Implementation of intervention†</td>
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<tr>
<td>New item</td>
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<td>Details of the experimental</td>
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<tr>
<td>treatment and comparator as they</td>
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<tr>
<td>were implemented</td>
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<tr>
<td>Recruitment</td>
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<td>Dates defining the periods of</td>
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<td>care providers (case volume,</td>
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<td>qualification, expertise, etc.) and</td>
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<td>centres (volume) in each group</td>
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<td>Numbers analyzed</td>
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<tr>
<td>Number of participants (denominator) in</td>
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<tr>
<td>each group included in each analysis and</td>
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<tr>
<td>whether analysis was by</td>
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<tr>
<td>“intention-to-treat”; state the</td>
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<tr>
<td>results in absolute numbers when</td>
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<tr>
<td>feasible (e.g., 10/20, not 50%)</td>
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<tr>
<td>Outcomes and estimation</td>
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<tr>
<td>For each primary and secondary</td>
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<tr>
<td>outcome, a summary of results</td>
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<tr>
<td>for each group and the estimated</td>
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<tr>
<td>effect size and its precision (e.g.,</td>
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<tr>
<td>95% confidence interval)</td>
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<td>Ancillary analyses</td>
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<tr>
<td>Address multiplicity by reporting</td>
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<tr>
<td>any other analyses performed, including</td>
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<td>subgroup analyses and adjusted analyses,</td>
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<td>indicating those prespecified and those</td>
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<td>exploratory</td>
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<td>Adverse events</td>
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<td>All important adverse events or side</td>
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<td>effects in each intervention group</td>
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</table>

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## Participant flow†

The number of care providers or centres performing the intervention in each group and the number of patients treated by each care provider or in each centre.
## Discussion

| Interpretation† | 20 | Interpretation of the results, taking into account study hypotheses, sources of potential bias or imprecision, and the dangers associated with multiplicity of analyses and outcomes | In addition, take into account the choice of the comparator, lack of or partial blinding, and unequal expertise of care providers or centres in each group | P 63 - 69 |
| Generalizability† | 21 | Generalizability (external validity) of the trial findings | Generalizability (external validity) of the trial findings according to the intervention, comparators, patients, and care providers and centres involved in the trial | P 70 |
| Overall evidence | 22 | General interpretation of the results in the context of current evidence |  | P 63 – 69, 73 |

*Additions or modifications to the CONSORT checklist. CONSORT = Consolidated Standards of Reporting Trials.

†This item was modified in the 2007 revised version of the CONSORT checklist.