



DOCTORAL THESIS

The Effect of BodyBalance Exercise on Core Stability and Back Pain

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The Effect of BodyBalance Exercise on Core Stability and Back Pain

by

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THESIS

A thesis submitted in partial fulfilment of the requirements
for the degree of Doctor of Philosophy

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Abstract

The overall objective of the three studies framed within this thesis was to investigate the effects of a BodyBalance workout on back pain participants from a predominantly physiological, but also a psychological and biomechanical perspective. The focus of the research was verifying claims made by the creators of BODYBALANCE™ and assessing the effects of their exercise programme on back pain sufferers.

The first study examined physiological and psychological changes in healthy adults (n = 34) following a 12-week BodyBalance training programme with participants divided equally between an exercise and a control group. Using an experimental repeated measures 2x2 factorial design, it investigated the interaction of BodyBalance for selected anthropometric, cardiorespiratory, strength, flexibility and psychological measures. The second study then utilised a cross-sectional design to compare differences more specifically for trunk endurance, balance and back pain disability between back pain (n = 26) and healthy participants (n = 26). The final study investigated the effect of BodyBalance in chronic low-back pain individuals (n = 14) following a 10-week programme, with an equal division of participants between the BodyBalance and control groups. It employed a mixed-method approach to assess balance, trunk endurance, flexibility and strength, alongside various psychological changes. This incorporated a 2x2 repeated measures quantitative design alongside qualitative interview data (n = 7) analysed through 'interpretive phenomenological analysis' (IPA).

Findings from study 1 displayed no significant changes in the control group following the intervention programme. However, significant changes in the BodyBalance group were noted for strength, flexibility and anthropometry in the trunk region along with reduced state anxiety. Results from study 2 reinforced the concept that individuals with chronic low-back pain were more likely to have weaker abdominal and back extensor endurance. Finally, study 3 revealed a significant improvement in the BodyBalance group for static balance with eyes open, back pain disability and some of the trunk flexibility and endurance measures. In addition, IPA extracted second order themes of back pain experience, understanding pain, coping strategies, identity, motivation and achievement. Overall findings of this thesis provide some support for the use of BodyBalance as a tool for the prevention and treatment of low-back pain.

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And in loving memory of my father
Ashraf Altaf Husain Khan

who I know would have been immensely proud of me.

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List of Abbreviations

Terms

ACL	Anterior Cruciate Ligament
ACSM	American College of Sports Medicine
AFAR	American Federation for Aging Research
ANOVA	Analysis of Variance
ASIS	Anterior superior iliac spine
ATM	Awareness through Movement
BAT	Body Awareness Therapy
BMI	Body Mass Index
BOS	Base of Support
BP	Blood Pressure
BWY	British Wheel of Yoga
CAM	Complementary & Alternative Medicine
CHIS	Complementary Healthcare Information Service
CLBP	Chronic Low-back pain
COF	Centre of Force
COG	Centre of gravity
COM	Centre of Mass
COP	Centre of Pressure
CS	Core stability
DBP	Diastolic Blood Pressure
EMG	Electromyographical

FEV ₁	Forced Expiratory Volume in the first second
FI	Functional Integration
FICSIT	Frailty & Injuries: Cooperative Studies of Intervention Techniques
FM	Fibromyalgia
FVC	Forced Vital Capacity
GP	General Practitioner
GRF	Ground Reaction Force
HLQ	Health & Lifestyle Questionnaire
HR	Heart rate
HRQL	Health Related Quality of Life
IVC	Inspiratory Vital Capacity
KGF	Kilogram force
LMI	Les Mills International
MANOVA	Multivariate Analysis of Variance
ME	Myalgic Encephalomyelitis
MS	Multiple Sclerosis
NIA	National Institute on Aging
NHS	National Health Service
NMD	Non-specific Musculoskeletal Disorders
OLBDQ	Oswestry Low Back Pain Questionnaire
POMS	Profile of Mood States
QDS	Quebec Back Pain Disability Scale
RMDQ	Roland-Morris Disability Questionnaire

ROM	Range of Motion
RQ	Romberg Quotient
SBP	Systolic Blood Pressure
SOC	Sense of Coherence
SPARC	Sports Performance Assessment and Rehabilitation Centre
STAI	Stait-Trait Anxiety Inventory
TCM	Traditional Chinese Medicine
TMD	Total Mood Disturbance
UK	United Kingdom
US	United States

Chapter 1

Introduction

“Modern body-building is ritual, religion, sport, art, science, awash in Western chemistry and mathematics. Defying nature, it surpasses it.”

(Camille Paglia, 1992; p82)

1.1 The research project

Research investigations into cardiovascular studio-based exercise formats such as aerobics or step aerobics, along with numerous papers related to strength training, dominate a large portion of the literature within the field of exercise. Research into the variety of “mind-body” modalities, however, proves to be somewhat more limited in availability. The term mind-body generally refers to a relationship of mind to body, but in this case applies more specifically to the array of exercise programmes that not only influence the physical functioning of the body, but also incorporate mental practices such as relaxation and meditation. Irrespective of the quantity of research available, the holistic approach to body enhancement seems to be in ever-increasing demand by today’s society. Regularly fuelled by press releases accompanied by a host of celebrity followers such as Geri Halliwell and Madonna, these classes have found themselves outgrowing the confines of local church halls and community centres and entering the realms of major sports and leisure complexes (Bupa, 2002).

Mind-body classes, now firmly established on leisure centre timetables, include traditional disciplines such as yoga, Pilates, Feldenkrais and tai chi intermingled with

more recently developed workouts such as BodyBalance. They are often regarded to be categorized under the heading of “core-stability” workouts, a term defined by Norris (2001; p11) to describe the benefits achieved through strengthening the central region of the body to provide a stable base for the movement of the limbs. These exercise programmes incorporate elements of muscle balance, flexibility and joint mobility. They have the prospective task of strengthening bones, ligaments and muscles, especially around the trunk region as this plays an essential part in spinal stabilization. Most have their foundations built around the notional concept of “neutral spine”, which can be described as the position providing the greatest comfort and stability with the least tension imposed upon ligaments and joints. Sometimes this position is also referred to in terms of the pelvis as being at “the midpoint of available range of motion between anterior and posterior tilt” (Herring and Weinstein, 1995; p1189). Participant awareness of this neutrally aligned position assists in the correct execution of exercises such as abdominal curls for the trunk musculature. In addition, it is argued that correct alignment would make the exercise a much more effective tool for targeting the “core” area.

To enhance core stability (CS) would require instigating improvements in the functioning of relevant trunk musculature. It would also involve acquiring beneficial changes in the mechanical structure of the spine itself. The primary stabilizers located within the trunk are the abdominal muscles, spinal intersegmental muscles, erector spinae group and quadratus lumborum (Herring, *et al.*, 1995; p1189). To be effective in their role, either as stabilizers or in movement, these components need to have appropriate strength, endurance and flexibility. Therefore, in principle at least, participation in mind-

body workouts should have a positive impact upon the posture of an individual through improved CS as well as influencing the degree of movement about a joint, reducing the possibility of injury due to muscular imbalances and reducing the occurrence of soft-tissue injuries.

1.2 The underlying problem

Posture or “the external visible relative arrangements of body segments in a given upright position” (Mester and MacIntosh, 2000; p241), is maintained against the action of gravity and is achieved through postural muscle tone. To gain balance, an individual requires their centre of mass (COM) to be maintained within the boundaries established by the “base of support” (BOS) (Massion and Woollacott, 1996; p1). To sustain this vertical stance against a variety of disturbances would call upon contributions from the visual, vestibular and somatosensory systems (Massion, *et al.*, 1996; p6). Although complex, this control process is essential to enable an individual to interact safely and efficiently with their surrounding environment. The skills demanded for this act of equilibrium, i.e. the balancing of forces and moments acting upon the body’s COM (Reimann and Guskiewicz, 2000; p37), develops in early childhood as the individual learns tasks such as how to control distal joints (e.g., the hip and ankle) or co-ordinate head, neck and trunk movements (Woollacott, Assaiante and Amblard, 1996). It then deteriorates in later life due to disorders associated with aging (Perrin, Gauchard, Perrot & Jeandel, 1999). The secondary spinal curve, that contributes towards the lower section of the conventional “S” shape, develops from about six months after birth (Bloomfield, Ackland and Elliot, 1994; p96) and is likewise exposed over time to a variety of

disorders, diseases and stresses (Norris, 2001; Porterfield, 1985; p271) as a result of modern, sedentary lifestyles. These afflictions ultimately undermine the strength and ability of the spine to perform everyday tasks and, following a downward progression stimulated by factors such as inactivity, can quite often lead to deterioration in the individual's "quality of life". A common manifestation of this is chronic low-back pain (CLBP).

1.3 The approach

The Office for National Statistics Omnibus Survey (Government Statistical Service, 1999; p1) found that 40% of adults reported a back pain episode of more than one day over the 12 months preceding the survey. This reinforced the work of Herring *et al.* (1995; p1172) who suggested that a commonly reported statistic for low-back pain was a "60-90% lifetime incidence" level with 70-90% of patients suffering recurrent episodes. This would mean that up to 90% of the population has at some point in their lives suffered from an onset of back pain. The consequences of this indicate an increased financial cost to employers, the National Health Service (NHS) and General Practitioners (GP's), as well as the psychological and physiological burdens imposed upon the individual themselves (Croft, Macfarlane, Papageorgiou, Thomas and Silman, 1998; p1356; Government Statistical Service, 1999; pp.2-3). Exercise, however, has been prescribed as a method of treatment for low-back pain as long ago as ancient Greece (Herring *et al.*, 1995). This, coupled with the suggestion "a generally healthy lifestyle, including moderate motion and exercise of the lumbar spine...may have some

preventative effects” would indicate that it still remains a cost effective therapy option (Nachemson, 1990; p36).

1.4 Research aims

Smidt (1994; p223) highlighted the lack of studies conducted on “trunk strength and endurance for patients with low-back problems” and suggested that “the effects of exercise treatment on low-back pain needs to be studied”. There is also only a limited amount of research published supporting the psychological and physiological benefits of the plethora of mind-body workouts now accessible to the community. Of these, many investigations are limited in reliability due to a variety of flaws such as the lack of a control group (Birkel and Edgren, 2000; Jain, Rai, Valecha, Jha, Bhatnagar and Ram, 1991; Madanmohar, Thombre, Balakumar, Nambinarayanan, Thakur, Krishnamurthy & Chandrabose, 1992; Wood, 1993). Hence, the objectives of this series of studies would be firstly to examine the principal benefits achieved from a selected CS programme, then compare factors of interest between popular mind-body formats and finally to apply an appropriate treatment to low-back pain sufferers to determine any changes. The aims are therefore:

Study 1: To establish the extent of validity for claims made by the promoters of BodyBalance.

Study 2: To determine whether differences exist between long-term practitioners of yoga, Pilates and BodyBalance in respect of four factors; namely balance, posture, core-strength and flexibility.

Study 3: To investigate the influence of mind-body exercise participation on CLBP sufferers.

[These original aims were amended during the course of the investigation; see pp39-46]

Overall, the principal aim being investigated is therefore that trunk stabilization benefits will be derived from CS exercises and CLBP sufferers will benefit from participation in these posture-orientated modalities.

1.5 Structure

This multi-disciplinary sports science research project requires input from a variety of sources. It is primarily grounded within physiological investigative methods. However, due to the holistic nature of this form of exercise there is also the necessity for input of a psychological and biomechanical nature. It has at its disposal a wealth of literature derived from research into a vast array of mind-body exercise programmes, irrespective of the limitations noted within a large proportion of these studies. These will range from studies into individual exercise modalities looking at aspects such as balance or flexibility, to investigations into their effect upon a multitude of ailments. The direction this research project will evolve may be somewhat influenced by the findings of each of the three independent studies.

Study 1: A comparison of the primary physiological and psychological responses in healthy adults arising from participation in a 12-week BodyBalance Training Programme.

Study 2: Further investigation into balance control, posture, trunk strength and flexibility in long-term practitioners of BodyBalance, yoga and Pilates.

Study 3: The effect of participation in BodyBalance exercise on CLBP sufferers.

With an increasing trend to encourage participation in holistic exercise, there is both the need and opportunity to develop research in this field.

Chapter 2

Holistic Programmes

“Health is a state of complete physical, mental, and social well-being and not merely the absence of disease and infirmity.” (*World Health Organization, 1958; p1*)

2.1 Mind-body Exercise

Trends in all aspects of life have changed continuously over the past two decades. We may, for example, look at how speech has changed with new words such as “Sudoku” being considered for inclusion within the Oxford English dictionary, or how British tastes have gone from fish and chips and “one meat and two veg” to curries and “pan asian”. In a similar manner, aerobics started from an organised collection of dance movements set to music, that could be accomplished by a large proportion of the general public. These classes were in most cases conducted within small local community venues. However, the future of “exercise to music” was influenced by a major leap in popularity as a result of the Jane Fonda era; this started with the successful launch of her first workout video in 1982 and was succeeded by a further twenty similar videos (Moodie, 2005). This brought with it aerobic fashions, avid followers and a “feel the burn” regime. Aerobic classes, now considered in a new light in terms of their classification as income earners, were better able to uphold their own value within the leisure centres’ timetable.

Aerobics is often placed into one of two categories. Firstly, there is low-impact aerobics that emphasises movements where at least one foot maintains contact with the ground (Egger & Champion, 1990; p104). Workouts using this format are often regarded

as appropriate for beginners, older participants and others requiring exercise at a lower intensity. In general though, most aerobic classes also tend to offer the alternative high-impact moves such as jumping jacks or jogging in which both feet momentarily lose contact with the floor. This provides the opportunity for the fitter, more active or co-ordinated participants to be challenged. The ensuing problem, however, was that through the inclusion of many high-impact, repetitive movements a variety of additional stresses on the musculoskeletal system could develop (Egger *et al.*, 1990). A study by Michaud, Rodriguez-Zayas, Armstrong & Hartnig (1993) established vertical reaction forces to be greater for high-impact dance manoeuvres and hence proposed low-impact to be a better option for minimising “lower extremity overuse injuries”. However, du Toit (1999) suggested that the reported high injury rate from aerobics in general might have resulted from the repetition element rather than the level of impact. In addition, high-impact exercise has been shown to have links with damage to the inner ear leading to conditions such as “vertigo, tinnitus, balance dysfunction and hearing loss” (Weintraub, 1994; p56). Considering the possible consequences of high-impact aerobics, but with studio workouts firmly implanted as a means of improving fitness, exercisers started to look at variations in the way they could improve their health.

Western and Eastern forms of treatment and conceptions of the maintenance of “health” are both founded within distinctly different ideologies (Chan, Cheung, Mok, Cheung & Tong, 2006). Countries such as the United Kingdom (UK) and the United States (US) have traditionally based their ideals upon biomedical methods of treatment. This orthodox paradigm describes the body as a sequence of parts, which can be repaired

or replaced as individual components. (Baer, 2001). However, the West is now beginning to show a greater interest in the extensive programme of complementary and alternative therapies that draw their roots from countries such as China and India (Dobos, Tan, Cohen, McIntyre, Li & Bensoussan, 2005). These treatment methods are often utilised to provide a holistic approach to patient care in a society that has embarked upon the route towards a “natural approach” and is empowering the patient to accept some responsibility for the role of preserving their health and preventing illnesses (Rosch & Kearny, 1985). In the UK, uses of traditional eastern remedies have increased in popularity to the extent that over the two-year period from 1998 to 2000, market research sources analysed a 23% growth in the sales of complementary medicines. This produced an estimated £115 million income in the latter year (Barnes, 2003). In conjunction with medical remedies, there are other alternative therapies that can be used to enhance health such as acupuncture, meditation, feng shui and, in particular, exercise (Donley, 2005).

Exercise is one of the treatment options inherent in Western and Eastern ideological approaches even though they both advocate different objectives. Exercisers in countries such as America, Europe and Australia tend to target specific aims such as increasing bulk, losing weight or improving particular aspects of fitness. Eastern ideology, on the other hand, undertakes a more holistic perspective. It considers the well-being of the body’s spiritual, psychological and physical parts “in terms of their contribution to the significance of the whole” (Treffrey, 2000; p737). Once this philosophy is introduced to western society it undertakes a process of adaptation to accommodate the new surroundings, thus transforming it into a modality “considerably

different than in its indigenous form” (Engebretson, 2002; p180). Irrespective of this, it still enforces a message that promotes “inseparability of body and mind in a positive state of health and well-being” (Rosch *et al.*, 1985; p1405). Mind-body exercise is based upon the premise of a two-way interaction between psychological thoughts, emotions and attitudes on the one hand, combined with physiological functioning of the body on the other (Ives & Sosnoff, 2000). Examples of this can be found in the philosophy behind tai chi which aims to maintain a balance between the “physical, psychological, spiritual and moral aspects of life” (Chan *et al.*, 2006; p308) or in yoga where the powers of “body, mind and soul [are bound] to God” (Engebretson, 2002; p181).

Mind-body exercise formats are becoming more prominent throughout the fields of health, fitness and rehabilitation, regardless of the extent of unsupported claims relating to their benefits or the possible legal ramifications that their usage could attract (Ives *et al.*, 2000). These workout programmes often propose that they will enhance performance, improve general health or facilitate rehabilitation, but they lack the research base that is currently available to conventional methods of exercise. Ernst, Cohen and Stone (2004) suggested this may be due to a number of reasons, including the difficulty of measuring certain “holistic” elements, a lack of available research funding or the fact that it is researched in accordance with standards set up to measure conventional forms of exercise. This does not seem to influence, however, the expanding popularity of mind-body exercise within the leisure market. The types of workouts that are currently “en vogue” include both traditional methods such as yoga and tai chi, alongside more recently developed programmes such as Pilates, Feldenkrais and BodyBalance.

2.2 Yoga

Yoga is a self-developmental practise that has been in existence for thousands of years (The British Wheel of Yoga (BWY), 2001; Hallo and Waller, 1999). Originating from India, it gradually evolved and branched out into varying forms based upon the teachings of the individual yogis or masters underlying the respective disciplines. One definition of yoga is as an eastern form of movement that describes an ability to “...join together to make union” (Lowis, 2000). By enhancing the capability of an individual to function in an integrated manner on four distinct planes, namely physical, mental, intellectual and spiritual, yoga is perceived as a useful tool in dealing with the stresses caused by modern lifestyles. It can therefore help to counteract the excesses of Western living exacerbated by factors such as inactivity and refined western diets that so often culminate in conditions such as insomnia, anxiety and depression (Yeoh, 1997; Field, 2011). With reference to the physical realm mentioned above, the maintenance of yoga poses or “asanas” encourages stabilisation and conditioning of the body by improving strength, alignment, co-ordination, suppleness, balance and flexibility. In a similar manner, the meditative practises of yoga draw attention toward self-awareness, breath control (pranayama) and the ability to become still (Yeoh, 1997; BWY, 2001). It has been proposed (Complementary Healthcare Information Service (CHIS) –UK, 2003) that the physical performance involved in yoga participation helps fine-tune each element of an individual until the body, mind and spirit are able to rest in a state of harmony.

Hatha yoga or as it is sometimes called “forceful yoga”, was introduced to the west in the 1960s, having extended its roots from the Indian sub-continent. It establishes

the foundation for the majority of yoga classes available in today's climate as it targets an equilibrium within both physical and mental energies (CHIS-UK, 2003; Engebretson, 2002). Incorporated under its umbrella are the most commonly practised styles such as Iyengar, Ashtanga, and Bikram. Iyengar's emphasis lies firmly on learning and perfecting techniques for asana performance, in conjunction with refining ideal body alignment. Founded by an Indian guru named B.K.S. Iyengar, it incorporates the use of props such as blocks and belts to assist with the more difficult poses, thus making it a suitable form for beginners. Each of the positions within the workout is held for up to 60 seconds, which is generally longer than in most other formats. Ashtanga yoga, on the other hand, is somewhat more advanced as it involves a specific sequence of asanas that take the body through a primary, secondary and advanced stage. The movements flow from one to another without any active pauses thereby producing an aerobic effect (Multitrax UK, 2002). It also advocates deep breath work that enhances the level of relaxation. Likewise, "Power yoga" is a workout of a similar level but with no predetermined order of poses. Bikram yoga is, again, another form of holistic exercise regarded as fashionable. Developed from the teachings of its namesake, Bikram Choudhury, it has matured under his guidance into a profitable business with a celebrity following. Born in Calcutta, India, in 1946, Choudhury was invited by President Nixon to live in the US in 1972 (Brzezinski, 2005). There he founded the "Yoga College of India" and developed a ninety-minute workout incorporating a specific sequence of twenty-six postures. Although suitable for varying levels of experience, the programme takes place in a room heated between 95° and 110°F (Maze, 2004). This would obviously result in participants sweating more and consequently assuming they may be working

harder. In addition, there is also the potential of a more effective flexibility workout. Finally, many other forms of yoga such as Sivanandra and Kudalini also exist; these emphasise the spiritual element and focus more upon breathing and meditation (CHIS-UK, 2003).

Findings from yoga investigations suggest that the workout has a positive effect upon physiological factors such as flexibility, strength and lung function as well as psychological factors such as mood states and stress (Ives *et al.*, 2000; Garfinkel & Schumacher, 2000). This makes it an ideal form of non-invasive therapy to either act alone or to compliment medical treatments for a vast range of current day problems such as hypertension, respiratory disorders, musculoskeletal ailments, pain management and mood disturbances. A survey by Long, Huntley and Ernst (2001) set out to determine which conditions complementary and alternative medicine (CAM) organisations felt benefited most from the therapy they practised. This resulted, in order of those most frequently cited, as stress/anxiety, headaches/migraine and back pain. Yoga, one of the many therapies considered, was regarded by the organisations as an effective means of treatment for each of these three conditions. It is also under this mind-body heading of yoga that we can discover the majority of peer-reviewed research pertaining to the other disorders indicated above. One matter to reflect upon when scrutinising relevant studies within this field are inherent weaknesses within research design, such as the lack of appropriate control groups, which puts the validity of their conclusions in doubt. In addition, due to the different physical intensities of the various types, results using one yoga style as the intervention are not directly comparable with those using another

(Williams, Petronis, Smith, Goodrich, Wu, Ravi, Doyle, Juckett, Kolar, Gross and Steinberg, 2005).

The first of the disorders mentioned, hypertension, is classified as a primary risk for cardiovascular disease and occurs when systolic/diastolic blood pressures are said to equate to or exceed a level of 140/90 mmHg (Stewart, 2001; p285). There are approximately 29% of adults within the US and 42% of adults in the UK, in the age range of 35-64 years, who fall within the category of being hypertensive (Hajjar & Kotchen, 2003; Laurent, 2004). Guidelines for the management of hypertension suggest that 30 minutes or more of "...regular aerobic physical activity" on most days may aid its prevention (Williams, Poulter, Brown, Davis, McInnes, Potter, Sever & Thom, 2004; p149). This message is reinforced by guidelines provided by the American College of Sports Medicine (ACSM) who recommend an exercise frequency of 3-5 times per week, for 20-60 minutes per session, at an intensity of 50-85% maximal oxygen uptake for mild hypertension or 40-70% if greatly elevated (Stewart, 2001; p288). In addition to the aerobic benefit derived through exercise, yoga formats include a secondary element of relaxation that also results in a positive impact upon blood pressure (BP) and therefore hypertension (Engebretson, 2002; Damodaran, Malathi, Patil, Shah, Suryavanshi & Marathe, 2002). One study on hypertension, by Murugesan, Govindarajulu & Bera (2000), looked at the pulse rate, mass, systolic and diastolic blood pressure (SBP and DBP) of thirty-three hypertensive individuals divided equally between three groups. Group 1 completed one hour of yoga per day for six days per week whilst group 2 received anti-hypertensive drug intakes and group 3 acted as a control for the total

duration of the 11-week period. The pre-post test results using ANCOVA showed both treatment groups to be effective in controlling the variables of hypertension. A further study on twelve healthy normotensive volunteers (Sung, Roussanov, Nagubandi & Golden, 2000), who were subjected to mental stress for 5 minutes, found that yoga breathing was the only intervention treatment to display a significant decrease in the time required for BP to return back to baseline ($P < 0.05$). Mental stress significantly increased SBP and DBP by 12% and 9% respectively. The average time taken for yoga to bring SBP to baseline was 2.7 minutes (3.7 minutes for the control group) along with a decrease in DBP of 11.2% (2.7% for control) at the fourth minute of relaxation. The two other intervention groups, which resulted in non-significant outcomes, were listening to classical music and the “sounds of nature”.

Further physiological conditions susceptible to improvement through the practice of yoga are those connected to respiratory complaints, such as a variety of different lung disorders including asthma, pneumonia and tuberculosis. Asthma accounts for a large proportion of the research conducted in this area, possibly because of the extent to which it affects the population, with approximately 20 million American (American Lung Association, 2005) and 5.2 million UK sufferers (Asthma UK, 2005). The same surveys also indicated a directly linked healthcare cost of \$11.5 billion in the US and £889 million in the UK, as well as many working days lost and deaths per annum. One study on respiratory endurance by Madanmohar *et al.* (1992) investigated the effects over twelve weeks of a 30-minute per day, six days per week yoga programme. This was conducted on twenty-seven male medical students for auditory/visual reaction times,

maximum inspiratory/expiratory pressures, and breath-holding times after expiration/inspiration as well as muscle strength (handgrip strength). The results after intervention displayed a significant improvement in all measures. The author does not indicate the use of an independent control group but instead refers to the pre-intervention test values as “control measurements” upon which the post-intervention values were compared. In a similar area of research a study on breathing efficiency and asthma by Birkel and Edgren (2000) investigated the effects of fifteen weeks of hatha yoga, emphasising postures, breathing and relaxation, on the vital lung capacity of 287 college students using Spiropet spirometers. They found a significant ($P < 0.001$) improvement for smokers, asthmatics and those with no lung disease. In this instance, the researcher states that no control group was used. Likewise, another study of forty-six asthmatics (Jain, *et al.*, 1991) between 11-18 years of age who followed forty days of yoga training for 2.5 hours per day, also displayed a significant increase in pulmonary function and exercise capacity measured using a spirometer, a 12-minute walking test and a modified Harvard step test. This research also suggested that pulmonary functional improvement is gender dependent as adolescent females showed a larger response than the males in this group. This appears to be based on the FEV₁ (Forced Expiratory Volume in the first second), which increased from 68.5 ± 15.9 to 74.7 ± 12.9 litres ($P < 0.01$) for males and from 63.0 ± 18.8 to 77.5 ± 14.7 litres ($P < 0.001$) for females, rather than the interaction between genders. Again, there is no reference given by the researcher as to the use of a control group. In essence, although many studies exist upon the effects of yoga, the possibilities of external influences have not been discounted due to the absence of adequate control measures.

Under the heading of musculoskeletal disorders and pain management lies a vast range of research into back pain along with a more limited amount of information on conditions not as often in the public eye. The BWY (2003), states that "...hatha yoga can help alleviate and prevent various forms of back pain...encourage greater awareness of correct body use...restore normal functioning and alignment". In a review of rehabilitative therapies by Hanada (2003), "alternative" treatments such as the use of yoga for musculoskeletal pain disorders, are considered. The author's conclusion indicates exercise to be "...the cornerstone of rehabilitation..." (p152), particularly when it enhances aerobic conditioning, strength, flexibility or proprioception. It states that yoga, prescribed as an alternative therapeutic modality often adjunct to medication or physical modalities, "...increases flexibility, strength, stamina...[and] self-awareness" (p153). Within its discussion on spinal pain it refers to a study by O'Sullivan *et al.* (op. cit. Hanada, 2003; p155) concerning forty-four patients diagnosed with spondylolysis or spondylolisthesis, congenital abnormalities that often result in back pain (Souhami & Moxham, 1998; p969). Participation in a 10-week exercise intervention programme, to strengthen deep abdominal muscles and the co-activation of lumbar multifidus muscles, produced a significant improvement for the treatment group, but only in respect of pain intensity and functional disability. Hanada (p155) suggested future research should "...target the effect on spinal pain of strengthening the core muscles ...including the multifidus [and]...transversus abdominis". Hanada's review highlighted the need for more studies, larger sample sizes, longer follow-ups and control groups that take place within a collective environment to compensate for the otherwise lack of social support. Williams *et al.* (2005) who assessed non-specific CLBP established similar results in a

study on a “relatively healthy” group of individuals with a mean age of 48.3 ± 1.5 years. Participants were randomly allocated to either a group that attended one 90-minute Iyengar yoga session a week ($n = 20$) or an educational control group ($n = 24$) for the duration of the sixteen week intervention period. This study acknowledged the publication of three further studies connecting yoga and back pain, two utilising unspecified forms of yoga and one with Iyengar that was a feasibility analysis on adherence rates to therapy. Williams *et al.* (2005) found significant reductions in self-reported “functional disability”, pain intensity and the use of pain medication for the exercise intervention group. There were no significant changes, however, for psychological measures such as coping strategies or for spinal range of motion (ROM). Their primary recommendation for future research was the inclusion of a more disabled population.

As mentioned earlier, research into other specific musculoskeletal conditions influenced through the practice of yoga also exist. One of these, arthritis, includes a study by Garfinkel *et al.* (1994) that considered the use of hatha yoga to alleviate musculoskeletal symptoms, which in this particular instance referred to osteoarthritis of the hands. Intervention comprised of a one-hour session, once a week for eight weeks; the variables assessed being pain during activity, finger range of motion, tenderness and strength. Of the treatment group ($n = 9$) a significant improvement was seen in the first three variables. There were no significant improvements seen in the control group ($n = 8$). Garfinkel *et al.* (1998) also conducted a further study to determine the effectiveness of a hatha yoga regime against the relief of symptoms associated with carpal tunnel syndrome.

The treatment programme was performed for eight weeks with two classes of 60 - 90 minutes each week, compared to the control group who were offered wrist-hand orthoses during this period to supplement current treatment. Significant improvements, in the yoga group only, were noted for pain reduction ($P < 0.05$) and grip strength ($P < 0.01$).

The final area of research under scrutiny for this study is that of mood states and anxiety. One study on mood states by Wood (1993) examined the effects of relaxation, visualization and pranayama on perceptions of physical and mental energy. Participants ($n = 71$) took part in two of each of the three treatments over a two weeks period; each session lasting 30 minutes. The main findings were that pranayama produced a greater increase ($P < 0.05$) in perceptions of energy, feelings of alertness and enthusiasm than both of the other two procedures, whilst relaxation methods made participants more sleepy and sluggish ($P < 0.05$). Although participants were divided into treatment subsets and the procedure administered to each group in a different sequence, the author stated that the research did "...not contain a placebo control group" (p255). Another study (Szabo *et al.*, 1998) used the Exercise-Induced Feeling Scale by Gauvin & Rejeski (1993) and the Subjective Exercise Experience Scale by McAuley & Courneya (1994) to compare the post-exercise effect after sessions of aerobics ($n = 41$), weight-training ($n = 45$), martial arts ($n = 44$) and a combined tai chi plus yoga group ($n = 25$). It found that the latter reported significantly higher levels of tranquillity than all the other exercise groups as well as lower psychological distress than the martial arts group ($P < 0.05$). However, at the time of testing both instrumental measurement scales were awaiting evaluation and the control was in the form of a music appreciation group ($n = 19$). A

further study on college students by Berger & Owen (1992) looked at the mood alterations associated with hatha yoga (n = 22), swimming (n = 37) and a health science lecture control (n = 28). The data was obtained via completion of a Profile of Mood States (POMS: McNair *et al.*, 1971, op. cit. Berger & Owen, 1992; p71) and a State-Trait Anxiety Inventory (STAI: Spielberger *et al.*, 1970, op. cit. Berger & Owen, 1992; p72) before and after the three treatments. Using MANOVA (Multivariate Analysis of Variance), the authors reported significant short-term mood benefits for the exercise groups on these three days, together with greater decreases on scores for anger, confusion, tension and depression. A review of exercise as a coping strategy for stress (Rostad & Long, 1996; p202) showed POMS and STAI to be the most commonly used instruments for studies under consideration. In their guidelines for future research, they also recommended the STAI as a psychological assessment tool for exercise and stress. Finally, Bail *et al.* (1995) op.cit. Telles and Naveen (1997) explored yoga's influence upon the rehabilitation of mentally and physically handicapped populations. Their study found a significant decrease in the stress of visually impaired children after three weeks of yoga intervention.

2.3 Tai chi

“Tai chi”, literally translated from its written Chinese characters, means “supreme ultimate”. The foundation of tai chi, grounded within three philosophical books written between 140 B.C. and 1000 B.C., defines tai chi in terms of its use as a self-defence mechanism and form of exercise for monks in addition to its links with Taoist philosophy (Marie, 2003). The underlying basis of Taoism revolves around “Yin” and “Yang”, the

symbolism of an ongoing yet complementary set of opposites present in the natural world. One such cycle can depict a balance of Yin as the manifestation of stillness and Yang as the manifestation of movement, which alternates changing one to the other as each attains its limits (Majka, 2006; Marie, 2003). Based upon these beliefs this concept therefore describes an interaction of two opposing forces that continuously fuel an infinite circle, thereby resulting in inner harmony and balance (Hartford Hospital, 2005). The effect of this harmony and balance on the body, attributed to the ongoing energy flow or “chi”, is ultimately apparent in the achievement of a sense of physical and spiritual well-being (Chan *et al.*, 2006). This has contributed to the evolution of tai chi as a form of conditioning within Chinese communities performed both for its ability to prevent ailments or medical conditions, such as arthritis and hypertension, as well as in anticipation of the benefits generally associated with exercise (Horstman, 2000). In the east, its popularity encourages the workout to take place in large public areas such as community parks (WholeHealthMD, 2000). Within the west, the form of tai chi that has developed is more a mix of yoga and meditation that emphasises the interaction of mind and body by using slow, flowing, rhythmic, circular movements in conjunction with mental concentration and postural awareness (Majka, 2006).

Tai chi, one of the main components of “traditional Chinese medicine” (TCM), lies alongside acupuncture and herbal remedies in the world of CAM. Within this field, disease signifies an imbalance in the energy flowing around the meridians or channels of the body and TCM therefore works to break down any blockages that inhibit this flow (Petrillo, 1997). The length of time tai chi has been in existence accounts for the various

styles that have gradually developed. Examples of the most popular schools followed, generally named after their founders, include Wu, Yang, Sun, Woo and Chen (Majka, 2006). Most classes, regardless of style, last for an hour and include elements of movement, breathing and meditation (American Cancer Society, 2006). Often regarded as a low-intensity form of physical activity, there is the suggestion that the practice of this discipline can benefit certain components of fitness such as strength, flexibility and balance (WholeHealthMD, 2000). If so, this would prove it to be of immense value to the older population in particular (Lan, Chen, Lai & Wong, 1999). Regardless of whether tai chi is undertaken for preventative reasons, maintenance of health or to assist recovery, the emphasis of relevant studies has been upon arthritis, balance enhancement including the prevention of falls, circulatory disorders, hypertension, multiple sclerosis and stress (WholeHealthMD, 2000; Cheng, 1999).

A large proportion of the studies into tai chi have investigated the effects upon older adults, possibly because of its suitability as an appropriate form of low-impact exercise for the specified population (American Federation for Aging Research (AFAR), 2004). One study, by Hong, Li & Robinson (2000), assessed the benefits of long-term tai chi on balance, flexibility and cardiovascular fitness of twenty-eight elderly male participants measured using resting heart rate, a 3-minute step test, single-leg stances with eyes closed, a modified sit-and-reach test and total body rotation. When compared with a sedentary control group ($n = 30$) the results displayed a significant improvement of $P < 0.05$ for standing on one leg with eyes closed and $P < 0.01$ for all the remaining tests administered. A second study on balance (Xu, Hong, Li & Chan, 2004) analysed

proprioception of the ankle and knee joints in elderly long-term tai chi practitioners (n = 21) against a second group of elderly long-term swimmers and runners (n = 20) and a third (control) group of elderly sedentary participants (n = 27). Ankle joint kinaesthesia, determined at the point where the participants detected passive motion, was $1.21 \pm 0.33^\circ$, $1.78 \pm 0.82^\circ$ and $1.95 \pm 0.66^\circ$ for the three groups respectively. The overriding conclusion proposed by the study was that the "...benefits of tai chi exercise on proprioception may result in the maintenance of balance control in older people" (p50). Additional reinforcement to the benefits of tai chi on balance includes statements provided by organisations such as the "National Institute on Aging" (NIA; 1996) who suggest "...tai chi can significantly cut the risk of falls among older people". They base this advice upon the outcome of projects conducted as part of a "frailty and injuries: Cooperative Studies of Intervention Techniques" initiative (FICSIT), designed to enhance "physical function" in later years. In particular, they refer to the findings of two reports from the May (1996) issue of the "Journal of the American Geriatrics Society" by investigators Wolf and Wolfson. The first study looked at the effects of 15-weeks of daily tai chi upon 200 participants aged seventy years or older and the second study at 6-months of weekly tai chi on 110 participants with an average age of eighty years. Subsequent research by Wolf, Sattin, Kutner, O'Grady, Greenspan & Gregor (2003), however, assessed the risk of falls in a forty-eight week trial of 311 adults between the ages of seventy and ninety-seven years. In contrast to the NIA conclusions, their findings indicated no significant difference over time in the risk ratio of falling for either the intervention tai chi group or the control group, who attended a "wellness education" programme. However, a trend towards a reduction in falls was noted in the tai chi group.

Finally, a review of thirty-one controlled experimental studies published in Chinese or English journals (Li, Hong & Chan, 2001) assessed the physiological responses to tai chi training, along with its consequential influence on general health and fitness. The evidence analysed for the cross-section of studies suggested that tai chi "...has beneficial effects on cardiorespiratory and musculoskeletal function, posture control capacity, and the reduction of falls experienced by the elderly" (p148). It concluded that tai chi "...is a moderate intensity exercise that is beneficial to cardiorespiratory function, immune capacity, mental control, flexibility and balance control; it improves muscle strength and reduces the risk of falls in the elderly" (p148). AFAR (2004) also point out that although most studies on tai chi do result in improvement, the extent of these vary widely between studies, as do study designs, making it difficult to quantify the overall benefits of the exercise form.

Neither the potential benefits of tai chi on a "younger" adult population nor other alternative elements of health and fitness seem to attract as much interest from researchers. One of the few exceptions to this, however, relates to cardiovascular risk factors. A study by Thornton, Sykes & Tang (2004) of seventeen healthy women aged between thirty-three and fifty-five years, resulted in a significant improvement in BP as well as dynamic balance. No significant changes were noted in the sedentary control group. A second study of 207 elderly participants (Thomas, Hong, Tomlinson, Lau, Lam, Sanderson & Woo, 2005), however, displayed no significant differences in BP after 12-months of tai chi training. Another area reported to be of benefit is the influence of tai chi on osteoarthritis. Although there is limited quality research in this area, a study by

Song, Lee, Lam & Bae (2003) on a group of older women ($n = 43$) found that 12 weeks of Sun style tai chi training resulted in a significant reduction in perceived pain ($P < 0.05$), stiffness ($P < 0.05$) and perceived difficulties in functioning in a physical capacity. The same study also noted significant improvements in balance and abdominal strength ($P < 0.01$), although it did not find any other significant changes in measures of strength or flexibility.

2.4 Pilates

Joseph Pilates, born in Germany in 1880, was a somewhat frail child who overcame a series of medical conditions such as asthma and rheumatic fever to become an accomplished gymnast, diver and skier (Pilates Foundation, 2006). In 1912 he found employment in England, initially as a boxer and then later as a circus performer and self-defence instructor (Power Pilates, 2005). The onset of World War 1, however, led him to become an intern and he used this opportunity to develop his system of exercises by teaching fellow internees. His skills later progressed towards the development of specialised equipment that assisted in the rehabilitation of injured war victims. Post war, he travelled back to Germany before finally emigrating across the Atlantic during 1926 to New York. It was here that Joseph Pilates and his wife Clara opened their first conditioning studio, based around the apparatus he had designed, which attracted many members from New York's gymnastic and dance community (Pilates Foundation, 2006). From amongst those pupils, many went on to open their own facilities teaching the principles learnt from the "Pilates" studio on Eighth Avenue. Publication of his techniques, outlined within books written in 1932 and 1945, also helped to continue the

teaching of his method after his death in 1967. As time elapsed, the workout has gradually evolved into its current form from which it provides actors, athletes, osteopaths and physiotherapists with a means of building strength without bulk in conjunction with an appropriate level of flexibility, mobility and relaxation (Robinson, 1997). Physical therapists who began to use Pilates in the 1980s, adapted its original function as a rehabilitation tool for injured dancers to a means of promoting stability. Following this, its application has expanded into areas such as movement dysfunctions and performance enhancement (Blum, 2002). “Pilates” has been considered a generic term since 2000 and is commonly used irrespectively of whether or not it applies to the original system instigated by Joseph Pilates (United States District Court, 2000).

In a similar manner to the majority of “mind-body” conditioning programmes that have filtered into the mainstream fitness industry, Pilates highlighted body awareness and co-ordination with the aim of correcting muscle balance and strengthening postural alignment (Robinson, 1997). Its aim, to strengthen and stretch the body, places particular emphasis on the abdominal and other core muscles groups often referred to within Pilates as the “Powerhouse” (Pilates Southwest, 2005; Muscolino & Cipriani, 2004). Encompassing eight main principles (i.e. centering, alignment, co-ordination, concentration, relaxation, breathing, stamina and flowing movements), the workout may be performed either on an individual basis or in a small group environment (CHIS– UK, 2003). Within group settings, the type of Pilates therapy practised is usually mat based and involves an hour-long performance from a repertoire of approximately forty exercises designed by Pilates (Larkham, 2006). Alternatively, exercises are performed using a

variety of specially designed exercise equipment and machines such as the “universal reformer”, the “Cadillac”, “wunda chair”, “magic circle” and small and large “barrels” (Cozen, 2000). One aspect of importance is again the limited amount of quality research supporting the purported psychological, physiological and biomechanical effects of Pilates. This is regardless of the countless claims and testimonials for its use in areas such as back pain, musculoskeletal injuries or neurological diseases. A search of the keyword “Pilates” on MEDLINE by Sperling de Souza & Vieira (2006) produced only 13 results, most of which had little direct relevance to the subject. Likewise, a search of the same keyword on SCIENCE DIRECT by the current author produced just 15 articles and 4 book reviews on 20/02/06. Sperling *et al.* (2006), whose observational and descriptive study was conducted over 22 months and looked at the demand in the leisure market for Pilates, found most participants to be middle-aged, inactive females suffering from some form of musculoskeletal pain. It reported posture, flexibility and rehabilitation as the most desirable goals of the 327 participants surveyed, by 38.8%, 32.1% and 24.2% respectively.

A large proportion of available research into Pilates looks at its use within rehabilitation, often as an addition to other methods of treatment. The idea behind this collection of exercises is the intention of changing habitual movement patterns through the correction of muscular imbalances between opposing muscle groups or between the left and right sides of the body (Cozen, 2000). Blum (2002) investigated the use of this therapy alongside chiropractic treatment for a female patient with long-term scoliosis. The “progressive severe back pain” suffered by the participant prevented her, prior to

commencing treatment, from carrying her 2-year old son or the equipment necessary for her job as a photographer. The duration of the case study took many years but, upon completion of treatment, the participant did stabilize sufficiently that she was no longer limited in her physical ability. The outcome of this case study led Blum to suggest that “the addition of Pilates therapy can be a useful tool in caring for patients with CLBP and deconditioning” (p1). Cozen (2000) in her review on the use of Pilates for ankle and foot rehabilitation also added that in order to enhance recovery, as in the case above, qualified professionals should always be on hand to supervise treatment and emphasised that misuse could prove detrimental to recovery. A number of the exercises in their original form, such as lumbar extension, may also be beyond the capabilities of many individuals with certain physiological dysfunctions and so caution is required when administering the therapy under these conditions (Stephenson, 2001). Stanko (2002; p21), whose clinical paper on the use of Pilates in women’s health suggests that “physiotherapists are in the best position to use Pilates as a treatment tool”, reinforces this view.

Pilates, as mentioned earlier, divides itself between apparatus specific and mat-based exercises. One study on the former, an investigation by Self *et al.* (1996), compared a biomechanical analysis of a demi-plié performed on a Pilates-based reformer to the actual dance movement. The implications derived from the findings of the study are that the reformer could be a useful tool in dance training or rehabilitation. It also highlighted the fact that rehabilitation on any single piece of equipment would be beneficial only to certain injuries but detrimental to others. This specific study implied that ACL (Anterior Cruciate Ligament) ruptures could be aggravated whilst

patellofemoral problems improved with a reformer. With mat-based Pilates, recent studies have concentrated on areas such as body composition to determine the influence of the exercise programme. An investigation by Jago, Jonker, Missaghian & Baranowski (2005) looked at the BMI, waist circumference and BP of girls aged eleven years of age ($n = 30$). The intervention group ($n = 16$) were offered five Pilates sessions per week over a four-week period with mean attendance evaluated as 75%. Findings analysed using a repeated measures ANOVA (Analysis of Variance), established significant time by group interactions indicating a reduction in BMI percentile ($P < 0.05$) along with a trend towards the reduction of SBP ($P = 0.071$). A further study by Segal, Hein & Basford (2004) looked into body composition as well as the flexibility of forty-seven adults (45 women and 2 men) attending a single one-hour Stott Pilates session each week for 6 months. Flexibility, measured as the distance between fingertip to floor as participants were instructed to try to “touch the floor [with] knees straight” (p1978), improved significantly ($P < 0.01$). There were no significant changes in height, body mass or lean body mass measured using multi-frequency bioelectrical impedance analysis. The author acknowledged “the absence of a suitable cohort of control subjects” (p1980) as a potential limitation of the study.

2.5 Feldenkrais

Like many complementary or alternative therapies such as acupuncture, homeopathy and yoga, the lesser-known modality of the Feldenkrais method is viewed with some scepticism within western society. Developed in the 1900s by Dr Moshe Feldenkrais, an Israeli scientist, physicist and engineer who arrived in the UK during the

1940s, its aim was to encourage movement and perception via the “Awareness through Movement” (ATM) philosophy (Worldwide Health Centre, 2006). The practical teaching of this “method” divides itself into two categories, ATM classes and Functional Integration (FI) sessions. The first incorporates a number of gentle exercises designed to access the sensory-motor processes of the brain and consequently enhance the body’s ability to “improve posture, flexibility, co-ordination, self image and alleviate muscular tension and pain” (Feldenkrais Guild, 2002). A sequence of instructions, given verbally in a group setting, encourages the participant to be aware of the kinaesthetic feel and gauge the extent of effort resulting from a movement. The second format, FI, is a “hands-on” system involving one-to-one tuition through which movement quality is influenced via touch (Frye, 2006). FI often acts as a supplement to ATM classes as it helps identify movement patterns that may cause discomfort or pain. Combined together, these components have led to Feldenkrais becoming an increasingly popular method for enhancing theatrical and sports performances as well as its prescription by health care professionals for managing a variety of disorders (Kerr, Kotynia & Kolt, 2002; p102). Its expansion, however, has been with minimal consideration for the “...limited body of empirical evidence for the Method’s efficiency...” that has been published (Kolt & McConville, 2000; p217). A large proportion of this existing evidence has produced conflicting findings, due mainly to methodological problems such as inadequately controlled studies (Ives and Shelley, 1998; Wright 2000). Of those reports with a more robust research design, it is in the areas of physiology, psychology and kinaesthesia that the influence of Feldenkrais upon improved flexibility, posture and muscular relaxation

(e.g. Hopper *et al.*, op. cit. Kolt & McConville, 2000; p217) was most adequately demonstrated.

One area where Feldenkrais has been purported to be of benefit is with non-specific musculoskeletal disorders (NMD). Malmgren-Olsson & Bränholm (2002) compared the effects of Body Awareness Therapy (BAT) (n = 23), Feldenkrais (n = 22) and various conventional physiotherapy treatments (n = 26) on patients with NMD. The BAT and Feldenkrais group participated in 20 sessions of therapy, including both ATM and FI for the latter. The data was analysed using the Swedish version of an SF-36, a 20-item Arthritis Self-efficacy scale and a 29-item Antonovsky questionnaire. The SF-36 is regarded as a useful tool in health-related studies to assess aspects of HRQL whilst the Antonovsky “Sense of Coherence” (SOC) scale examines dimensions of comprehensibility, manageability and meaningfulness. The results found few significant differences between the three disciplines; however, significant improvements of HRQL and self-efficacy of pain were established in all three disciplines over time. The findings, in accordance with “effect-size” measurements, were relatively higher in BAT and Feldenkrais and hence the authors concluded that BAT and Feldenkrais “...seemed to improve health-related quality of life (HRQL) and self-efficacy of pain to a somewhat higher degree than conventional physiotherapy” (p308). A further area closely linked to NMD is fibromyalgia (FM) syndrome, a musculoskeletal pain and fatigue disorder (Fibromyalgia Network, 2006). FM patients (n = 20) participated in a pilot study where they attended one FI and two ATM sessions per week for 15 weeks whilst a control group (n = 19) participated in an education and “pool” programme (Kendall, Ekselius, Gerdle

and Soren, 2001). A significant change ($P < 0.01$) was noted for “balance” measures post intervention in the Feldenkrais group but the author found the effect not to be sustainable at the six-month follow-up analysis. This pilot study also encountered many difficulties resulting in a smaller number of participants and incomplete data. A later review (Gard, 2005) summarised the findings of 8 studies that compared the effects of various combinations of the effects of basic BAT, Mensendieck, Feldenkrais and conventional physiotherapy. Two of these focused on a Feldenkrais group of which one, involving NMD, showed a smaller improvement in Feldenkrais than in the basic BAT group for pain symptoms and psychological measures. In a similar fashion, Feldenkrais intervention has been the subject of research in connection with multiple sclerosis (MS), a chronic disease of the central nervous system without a known cure (Huntley & Ernst, 2000; p97). A study by Johnson, Frederick, Kaufman & Mountjoy (1999) investigated the Feldenkrais method on a group of MS patients ($n = 20$) using a crossover design where the control was a “sham” session. Participants assigned initially to the experimental or control group for 8 weeks, later changed to the alternative group for the remaining 8 weeks. Significant differences were observed for a reduction in perceived stress and lowered anxiety in the Feldenkrais intervention group, although all other measures such as changes in MS symptoms or degree of functional ability proved non-significant.

Certain studies have utilised Feldenkrais to determine its effect on psychological factors. Laumer, Bauer, Fitcher & Milz (1997) provided a group of eating-disorder patients ($n = 15$) with a series of questionnaires before and after participating in a 9-hour

course of Feldenkrais. Compared to the control group who were also eating-disorder patients ($n = 15$) but who did not participate in the course, the intervention group showed increased contentment, acceptance and familiarity with their own body. Kerr *et al.* (2002) chose to investigate a different psychological aspect by examining the ability of the Feldenkrais method to reduce state-anxiety. Volunteers ($n = 45$), divided into two groups based upon whether they were new to Feldenkrais ($n = 18$) or had previous experience of ATM lessons ($n = 27$), participated in a 1-hour session each week for 10 weeks. From these groups only 3 new and 20 ATM experienced participants completed the requirements of the study. Volunteers who “declined” participation in the proposed 10-week intervention programme ($n = 55$; 13 new, 42 ATM experienced) were offered an alternative single 1-hour lesson at week five. The state scale of the STAI, administered prior to the beginning of the first lesson, before and after the fifth lesson and subsequent to the final lesson, showed state anxiety scores to decrease significantly ($P < 0.01$) for both the single lesson and the 10-week programme when compared with baseline. No mention appears within the literature of a non-exercising control group. Kolt *et al.* (2000) undertook a similar study determining the effects of Feldenkrais using POMS-BI (1982) on a sample of 54 physiotherapy students, randomly allocated to either a Feldenkrais training group ($n = 17$), a relaxation group ($n = 20$) or a “no training” control group ($n = 17$). A POMS scale was completed prior to the first and fourth interventions, upon completion of the fourth intervention and again a day later. A 3x4 factorial ANOVA showed that the “composed-anxious” scores of POMS did vary significantly over time ($F_{(3,153)} = 14.62, P = 0.001$) but further post-hoc tests showed that participants in all the groups were less anxious. When considering the female participants only,

however, both treatment intervention groups reported a significant reduction in anxiety levels on completing the fourth lesson in comparison to those participants in the control group.

2.6 BodyBalance

In order to understand the essence of BodyBalance we need to summarise the combined contribution of its respective components that were discussed earlier; namely yoga, tai chi, Pilates and Feldenkrais. The first of these, yoga, is a workout that merges the physical, mental, intellectual and spiritual aspects of an individual. It advocates the practice of maintaining poses, enhancing stillness and improving breath control in an attempt to influence factors such as alignment, flexibility, mood states and stress. In a similar manner tai chi, based upon the Taoist philosophy of Yin and Yang, uses slow, rhythmic movements that encourage mental concentration and postural awareness to reinforce strength, flexibility and balance. The speed, movement composition and resulting benefits have a bearing on why tai chi is a popular exercise regime for the older population. Pilates, both mat-based and equipment-orientated, is a tool often used by actors, athletes, osteopaths and physiotherapists to rectify muscle imbalances and to strengthen postural alignment with an emphasis on the “core” muscle groups encapsulated within the Pilates term “Powerhouse”. Finally, Feldenkrais promotes awareness of the kinaesthetic element and level of effort required for a movement pattern via both ATM classes and one-to-one FI. Actors, athletes and health care professionals therefore often use it to influence flexibility, posture and muscular relaxation. All of these modalities are different in terms of the philosophy behind their inception yet all are

similar in respect of the way they try to use a combination of mind and body practices to bring about comparable changes in both physiological and psychological spheres. All require differing levels of effort and varying degrees of internally and externally focused components yet each can contribute towards improved flexibility, body alignment and stress related disorders. This may be one reason why they were considered viable ingredients in the development of the “BodyBalance” workout programme.

BodyBalance is the name assigned to one of the pre-choreographed group exercise programmes developed and licensed for health and leisure centres worldwide by Les Mills International (LMI). As with all LMI workouts, the choreography is designed around a specific number of music tracks. The advantage of this flow of constant music is its effect on the way exercise influences mood (Karageorghis and Terry, 1997). Examples of other packages they have designed include BodyPump, BodyCombat, RPM (stationary bicycles), BodyJam and BodyAttack, a circuit style of workout. This Auckland-based company, through simply repackaging existing exercise formats, has been able to expand and achieve ongoing income from leisure centres and instructors through obligatory purchases of music, compulsory workshops, training courses and merchandise. Its commercial awareness has guided the company towards developing both traditional studio exercise programmes as well as restructuring alternative options that did not lie primarily in the “studio” environments. Its philosophy advocates the “Body Training Systems” umbrella as a method of revolutionising the aerobics industry that would in turn contribute towards a reversal of the negative trends in studio usage, as depicted by the American Sports Data 1987-97 Trend Report (op. cit. LMI, 1999; p111).

In principle, this would therefore increase the range of easily accessible exercise programmes within the community and thus improve general levels of activity as well as promoting a range of additional health benefits.

LMI suggest that the “BodyBalance” workout combines the teachings of yoga, Pilates and Feldenkrais (Les Mills International, 1999; p110). Publicity literature produced by the company proposes benefits arising from BodyBalance include aesthetically improving body tone and posture, even to the extent of making the exerciser “look a size smaller and three inches taller”, enhancing the physical efficiency of the body’s physiological system and alleviating aches and pains (LMI, 2000). Furthermore, as a result of participation, it alleges that improvements are created by changes in muscle strength, flexibility, mobility, balance, co-ordination, focus, concentration, postural imbalance and relaxation. From this list of components, balance and posture are ingredients of prime consideration as the BodyBalance exercises “focus on strong core (abdominal and back) stability” and help to “restore the body’s symmetry”. As there has been no peer-reviewed, independent research conducted on BodyBalance, the foundation of the current study will be based upon investigations into the holistic practises from which it has been compiled. In particular, studies related to yoga are relevant as this modality forms the greatest proportion of the said workout.

Based upon evidence accumulated within the archives of yoga, tai chi, Pilates and Feldenkrais, a reasonable assumption is that BodyBalance should benefit a wide range of conditions. Firstly, it may have a positive influence upon the variables of hypertension in

both hypertensive and normotensive participants (Murugesan *et al.*, 2000; Sung *et al.*, 2000). In addition, BodyBalance may improve respiratory disorders in asthmatics and smokers and assist maintenance of healthy lung function in those diagnosed with “no lung disease” (Madanmohar *et al.*, 1992; Birkel *et al.*, 2000; Jain *et al.*, 1991). Thirdly, with respect to musculoskeletal disorders such as osteoarthritis and CLBP, BodyBalance could assist with the reduction of pain intensity, functional disability and medicinal dosages required. This in turn would lead to an improvement in an individual’s health-related quality of life (HRQL) and self-efficacy of pain (O’Sullivan *op. cit.* Hanada, 2003; Williams *et al.*, 2005; Garfinkel *et al.*, 1994, 1998; Malmgren-Olsson, 2002, Blum 2002). Fourthly, with respect to psychological disorders, the exercise programme could lower anxiety, stress and increase feelings of tranquillity, and contentment (Szabo *et al.*, 1998; Berger *et al.*, 1992; Laumer *et al.*, 1997; Kerr *et al.*, 2002, Kolt *et al.*, 2000). Penultimately, in relation to the elderly population, there is the prospect of fewer falls as a consequence of improved balance (Hong *et al.*, 2000, Xu *et al.*, 2004; Li *et al.*, 2001). Finally, there is the possibility that the components of fitness will be enhanced, in particular flexibility, muscular strength and cardiovascular fitness (Segal *et al.*, 2004; Hong *et al.*, 2000; Self *et al.*, 1996, Li *et al.*, 2001). It should be noted that there are many instances where no significant changes have resulted in the above factors as a result of mind-body exercise and there is obviously no guarantee that the benefits gained are sustainable (Johnson *et al.*, 1999; Kendall *et al.*, 2001; Garfinkel *et al.*, 1994; Williams *et al.*, 2005; Wolf *et al.*, 2003).

2.7 Study Design

2.7.1 Methodology

The nature of the workouts reviewed in this chapter has raised questions as to the type of research design appropriate for investigating the “mind-body” concept. The name in itself implies that this category of workout influences the mind in addition to the body, possibly with equal weighting. Previous literature, however, appears to rely primarily on quantitative measures that could limit the richness of “mind” data. “Body” elements assessed have appropriately used physiological measures for variables such as the components of fitness, BP and lung capacity whilst the “mind” aspect were measured with a series of questionnaires that looked at factors such as mood states, anxiety and pain disability. Only one example of qualitative research was included in the review, which was a case study relating to the long-term treatment of scoliosis in a female patient. The problem of continuing with this predominantly quantitative approach would be whether it was sensitive enough to detect those changes resulting from workout components, such as levels of stress and anxiety induced by meditation or, indeed, draw out the subtlety of change in the perception of back pain. Therefore, the decision was made that a more balanced research design, using both quantitative and qualitative research methods could prove beneficial. This would require an element of flexibility as to the ratio according to the requirements of each investigation within the thesis.

The objective of the first study was to gain some insight into the physical and psychological effect of a 12-week mind-body exercise intervention upon healthy adults. Consequently, since both before and after measures would be required, a longitudinal

design was necessary. Following previous methodology, the analyses of physiological and biomechanical variables, along with psychological questionnaires that determine influence of the programme upon mood states and anxiety, would result in quantitative data. The measurement of these variables would take place at individual, two-hour preliminary and post-intervention sessions in the biomechanics laboratory using pre-selected practical field tests. One reason for the preference of such tests is the provision of useful feedback to the participant, as they are generally easier to understand, potentially more meaningful to the individual along with the possibility they could enhance self-esteem and perception. This aspect is of particular relevance to the final study, although it in fact pervades the whole investigation. Furthermore, should the need arise, the field tests could be easily transported to leisure centres or other testing sites. An additional consideration is the completion of sufficient tests to produce a comprehensive picture of changes, in addition to allowing the testing sessions for all participants to be concluded within a two-to-three week window.

The objective of the second study was to establish whether a difference existed between back pain and non-back pain groups (see p43 for the reason groups changed from yoga, Pilates and BodyBalance) for variables found from previous studies to have influenced CLBP. These predominantly focussed on measures around the trunk region, concentrating on variables such as balance and flexibility, thereby resulting in quantitative data. Due to the analysis of data at the same point in time, a cross-sectional design would be required. The allocated time of 90 minutes for each testing session per individual would consist of field tests for the reasons explained above. This is also in line

with a number of existing studies using similar tests, thus allowing greater opportunity for comparison of results.

The objective of the final study was to assess the physical and psychological effects of a 10-week BodyBalance exercise intervention upon participants displaying symptoms of CLBP. Like the first study, it required a longitudinal design to assess selected variables before and after treatment. Testing sessions for each individual allowed two hours to ensure sufficient time for participants with acute back pain or cautious movement patterns as a consequence of their pain, to complete the task without feeling under undue pressure. Although some measures within this study would produce quantitative data, the prominence of back pain in participants would also call for a qualitative approach. This could be included through semi-structured interviews that investigate the participant's perception of back pain and how it affects their quality of life or via a case study that highlights the impact upon an individual from their own personal perspective.

2.7.2 The Journey

An overview of research design and test selection has been outlined above. However, the structure of the thesis did not follow a conventional format and before progressing to the remaining literature review and the subsequent series of studies, it felt appropriate to explain the reasons why the thesis topic was selected and why changes were made that altered its original aims.

The interest in the Les Mills family of exercise programmes developed as the result of an earlier study by the author in which BodyPump, another Les Mills programme, was applied as an exercise intervention for a longitudinal BSc dissertation. One advantage was that the pre-determined nature of its choreography, with its inherent structure and written clarity, lent itself to scientific study since it could assist reliability. The idea of then combining mind-body exercise with relief from back pain arose from perusal of BodyBalance promotional literature listing claims of possible health benefits. This was fuelled further by observations made by the author during many years of teaching a variety of workout programmes that highlighted the extent to which limitations of knowledge existed within the aerobics industry, specifically in relation to mind-body type formats. The author also felt a moral obligation, due to actively teaching some of these programmes, to investigate the Company's claims. In addition, existing publication and internet articles suggested that Les Mills workouts were being undertaken at clubs internationally, so creating a worldwide following. Despite such popularity, the claims made by the company as to the benefits of participation, particularly concerning BodyBalance, remained largely unsubstantiated. Finally, there exists much discussion about the relationship between trunk musculature and back pain. The decision to investigate this relationship using popular mind-body genres was determined at the outset, for the reasons noted above, although the decision to select BodyBalance as the intervention for the final study came only after analyses of the first study's results.

The original intention of the research was therefore to establish the most appropriate mind-body workout format for use as an intervention and then use that

specific form of exercise to conduct a longitudinal study on back pain sufferers. To accomplish this task was not as straightforward as anticipated. In following the natural progression of the studies, allowing adaptations to the aims of the next study according to findings of the one completed, the thesis followed a much more convoluted route than expected. This resulted in a deviation from the original aim in order to gain the desired outcome.

Upon commencement of the study, the proposed title of the thesis was “The Effect of Mind-Body Exercise Formats on Core Stability”. The format selected had to be one that not only influenced relevant trunk and psychological measures but also, due to its impending application, have the ability to be safely performed by a CLBP population. Popular formats considered suitable were shortlisted as BodyBalance, yoga and Pilates. At this point, it became apparent that no peer reviewed research existed on BodyBalance. The first task therefore had to become an investigation into the effects of just the BodyBalance programme.

Study 1 was originally entitled “The Influence of Mind-Body Exercise on Postural Control: A Comparison of the Physiological & Psychological Responses in Adults Resulting from a 12-week BodyBalance, Yoga or Pilates Training Programme”. With the necessity to learn more about BodyBalance, before conducting any assessment between different programmes, it became “A Comparison of the Physiological and Psychological Responses in Adults: A 12-Week BodyBalance Training Programme”. Since the literature review focussed on studies of the underlying components of

BodyBalance; namely yoga, tai chi, Pilates and Feldenkrais, it was assumed that BodyBalance could benefit the same variables of body composition, body mass, lung function, BP, components of fitness, balance, posture, anxiety, stress, and mood states highlighted by these earlier studies. This was therefore the foundation for selecting the test battery. The study concluded that BodyBalance could benefit strength, flexibility and girth measurements around the trunk region in addition to reducing state-anxiety. Having demonstrated that at least some of the claims made for BodyBalance were genuine, it was decided to concentrate on their claim that the programme could “alleviate aches and pain”; more specifically, back pain.

The original aim for study 2 at the outset was to establish whether differences existed between long-term practitioners of yoga, Pilates and BodyBalance in terms of balance, posture, core-strength and flexibility. This was in order to determine which of the three options would be the most appropriate intervention for back pain sufferers. However, the findings of study 1 had shown that BodyBalance not only influenced the trunk region for healthy participants but could also be more suitable for a group of CLBP sufferers as it was designed to allow relevant adaptation of the exercises according to individual physical limitations. In addition, as discussed above, it offered a more consistent routine by virtue of the listed choreography when compared to yoga or Pilates. With BodyBalance selected as the intervention of choice there remained one question that needed consideration before undertaking further interventions; namely, whether a foot scan or force platform would be more suitable for balance measures. This followed errors resulting from electrical noise in Study 1. As a result of this technical study, only

the foot scan was used for “centre of pressure” (COP) displacement measures for the remainder of the investigation. This second study was exploratory in nature and was used to assess whether additional measures, as suggested by the back pain literature, for balance, trunk endurance (Sørensen and 60s back-extension test) and back pain disability (Quebec Back Pain Disability Scale) would help to distinguish between those with and without CLBP. The title was appropriately amended to “Investigating Measures of Postural Control and Trunk Endurance as Indicators of Chronic Low Back Pain”. Power analysis (Gpower) determined a sample size of 52 resulting in a CLBP group (n = 26) and a non-back pain control (n = 26). No significant difference was found for balance but a significant difference between the groups was noted for trunk endurance tests and self-reported back pain disability. These would therefore be useful measures to include in the final study.

Study 3 went back to the original aim of the thesis to investigate mind-body exercise on CLBP sufferers with “An Investigation into the Physiological and Psychological Responses of Adults with Chronic Low Back Pain: A 10-week BodyBalance Training Programme”. Some tests used in Study 1 were excluded from the battery because of their non-relevance to an investigation on back pain and to minimise potential fatigue risks for the participants. Additional measures were then added to the test battery, such as a further pain disability questionnaire (Oswestry Low Back Pain Disability questionnaire), interviews and a case study, in order to provide greater insight into the psychological aspects experienced by participants. The self-report questionnaire, Quebec, used in study 2 proved useful in assessing back pain disability and it was

deemed appropriate to now include the Oswestry as a way of increasing or supporting the information that could be gained. Likewise, it was considered that a case study could help expand upon the information relating to an individual's perception of such pain.

Chapter 3

Core stability & the back

“Moderate exercise and toil, so far from prejudicing, strengthens the body and consolidates it.” *Dr Benjamin Rush, c1700*

3.1 The Spine

In order to discuss CS it is essential to start by looking at the composition of the trunk and in particular the vertebral column. Designed as a weight-bearing structure it is primarily divided into five sections with a total of 24 moveable bony segments; 7 cervical, 12 thoracic and 5 lumbar, in addition to a fused sacral and coccygeal segment (Remer, *et al.*, 1995; Gargan and Fairbank, 1996). The size of each of these segments increases gradually from the first cervical vertebra, travelling down towards the sacrum (Remer, *et al.*, 1995; p1068). The spine performs many important functions, including protection for a delicate spinal cord, support for the head, neck, pelvic girdle and abdominal structures, a point of attachment for the thoracic cage and a means of transmitting weight onto the legs (Nordin, *et al.*, 2001; p257; Gargan, *et al.*, 1996; p2). In partnership with the intervertebral discs these vertebrae also act as a shock absorber against external stresses imposed upon the trunk (Remer, *et al.*, 1995).

The shape of the spine is emphasised visually on adults by the display of four curves when viewed from a sagittal perspective, two being the primary curves and two the secondary. The first primary curve originates in the foetus due to the rounded position assumed in the womb and this later develops into thoracic kyphosis and sacral

kyphosis. The secondary curvature, which is the cervical lordosis and lumbar lordosis, develops respectively as the infant starts to raise their head up and later begins to stand (Norris, 2001; p2; Gargan, *et al.*, 1996; p2). These curves help to provide the spine with an increased ability to absorb stress and promote flexibility (Remer, *et al.*, 1995).

Movement in the trunk basically takes place at the apophyseal joints and intervertebral discs (Souhami and Moxham, 2002; p1185; Nordin, *et al.*, 2001; p260). It is achieved by vertebrae, acting as levers around the pivot points provided by facets and discs, that are attached to a multitude of ligaments and muscles functioning respectively as movement activators and restrainers (Remer, *et al.*, 1995; p1067). The ROM between each two adjacent vertebrae is small and limited so all movements are performed by the inclusion of several segments. In addition, factors such as age and gender would have some influence on an individual's ROM (Nordin, *et al.*, 2001; p263). Alongside movement, discs and ligaments work to provide an intrinsic structural stability to the spine, whilst the muscles help to provide extrinsic support (Nordin, *et al.*, 2001; p260). Ligaments act as the main tensile load-bearing structure working passively to prevent excessive motion (Buckwater, Einhorn and Simon, 2000; p773). Likewise, discs work to distribute any load applied to the spine and restrain excessive movements within the trunk (Nordin, *et al.*, 2001; p258).

The amount of motion at different levels of the spine varies greatly with the cervical spine having the greatest overall mobility, followed by the lumbar and then the thoracic (Remer, *et al.*, 1995). The thoracic spine almost acts as a transition between the

cervical and lumbar regions, limiting movement to the extent that facilitates the mechanical requirements of the rib cage and lungs. The lumbar spine, when working in conjunction with the hips, provides for most movements associated with the trunk (Buckwater, *et al.*, 2000). It is subjected to significantly greater loads than other areas of the spine (Nordin, *et al.*, 2001). Finally, the main types of movements that can be performed from the trunk region are in three planes; namely flexion or extension, lateral flexion, rotation and circumduction (Remer, *et al.*, 1995; Nordin, *et al.*, 2001).

3.2 Muscles

It was mentioned earlier (section 3.1) that muscles act as restrainers and activators to assist movement in the trunk. An interactive play between agonistic and antagonistic muscles initiates, controls and modifies movement, in addition to promoting spinal stabilization (Smidt, 1994). This group of trunk muscles can be further divided into the flexors and the extensors. The flexors are predominantly the abdominal and psoas muscles that lie for the most part anterior, whilst the extensors lie mainly posterior to the vertebral column (Nordin, *et al.*, 2001; p260). From amongst these, the muscles playing the greatest role in enhancing stability and mobility of the lumbar spinal region are the four abdominal muscles consisting of the rectus abdominis, external obliques, internal obliques and transverses abdominis (Warden, Wajswelner and Bennel, 1999). These are also the muscles that initiate flexion of the trunk succeeded by upper body weight (Nordin, *et al.*, 2001; p265). The psoas major was for some time regarded as a stabilizer of the trunk, during movements such as extension and flexion, but recent studies suggest its design is principally for hip flexion. The lumbar back muscles, on the other hand,

exert an action on the lumbar spine even in cases where not directly attached. They respond with minimal activity when the body is in an upright position, but increase activity in forward flexion and the returning extension, when their eccentric contraction controls the extent and speed of the movement. For the same angle of flexion the larger the external load being lifted the greater will be the extent of back muscle activity. At approximately 90% of maximal flexion, some individuals reach a “critical point” where the spinal load bearing transfers from the back muscles to the posterior ligaments, leaving the erector spinae inactive. Back pain sufferers are one group where this relaxation effect is not always observed, although the reason is yet undetermined. Possible explanations have included the inhibition to flex completely due to pain or an abnormal muscle reaction to the lengthening process. The extensors also initiate hyperextension from an upright stance, following which it is controlled and modified by abdominal muscles as the angle of the movement increases. Furthermore, for maintaining posture the relevant back muscle is recruited to correct any displacement in accordance with the direction of the movement (Macintosh and Bogduk, 1994; p189; Nordin, *et al.*, 2001; p265; Buckwater, *et al.*, 2000; p780). Finally, although most studies investigating lumbar trunk activity study the abdominal muscles, many have considered back muscles such as the latissimus dorsi, multifidus and erector spinae.

The definition of muscle strength and muscle endurance is “...the ability of a muscle or a group of muscles to exert force” and “...the point at which muscle fatigue is observable” (Buckwater, *et al.*, 2000; p778). These elements, in relation to the trunk, have a certain degree of influence over the performance of everyday tasks and activities.

Along with appropriate balance between the long trunk flexors and extensors, they also play a major role in the prevention and treatment of low-back pain (Smidt, 1994). In order to study the isolated muscle group capabilities of the trunk a variety of methods are available. One of these, a dynamometer, is a popular choice when performing strength testing using either isometric or isokinetic measurement techniques. Factors that would need to be taken into account that could influence the result include age, gender and pain. This piece of equipment is also used for dynamic endurance tests, although fatigue can easily be tested for by maintaining a postural stance or performing an activity to exhaustion. Smidt (1994) highlights the fact that studies indicate abdominals fatigue faster than back extensors when performing repeated contractions. With horizontal trunk maintenance, CLBP sufferers have significantly less endurance than individuals with a healthy back (Buckwater, *et al.*, 2000).

Semi-direct methods of measurement tend to be a preferable means of investigating postural muscle activity, as opposed to the more complex direct methods that are not always justifiable for general use. These methods can also be used to study other aspects of the spine such as the effects of externally lifting objects, motor control strategies available for movement of the trunk, the efficiency of trunk strengthening exercises and their desired form for back pain rehabilitation (Nordin, *et al.*, 2001; p267; Buckwater, *et al.*, 2000). Clearly, the position of the body would be important in determining the loading applied to the lumbar spine, with the load being least with the body lying in a supine position. It then becomes slightly greater during supported sitting or relaxed standing and even greater still with unsupported sitting positions and standing

with the trunk flexed or by lifting external loads (Wilke, Neef, Caimi, Hoogland and Claes, 1999).

The first of two techniques generally utilized to establish spinal loading is a mathematical model of force estimation based on electromyographical (EMG) muscle recordings along with biomechanical moments and forces. The second is EMG measurement of trunk muscles that are used to indicate the level of tension developed within the muscle (Nordin, *et al.*, 2001; p267; Buckwater, *et al.*, 2000; p779). The main advantage of using EMG analysis is the availability of non-invasive surface electrodes and the large pick-up area. However, such equipment is regularly prone to affliction by a variety of intrinsic and extrinsic difficulties, with obvious limitations to consider including cross-talk, electrode placement, subcutaneous fat and skin impedance (Vink, Daanen and Verbout, 1989; Ng, Kippers, Parnianpour and Richardson, 2002; De Luca, 1997).

The first such study under consideration that used EMG on trunk musculature was on a group of male participants both with ($n = 15$) and without back pain ($n = 28$). Ng *et al.* (2002) examined normalized EMG activity of 6 bilateral trunk muscles, 3 pairs of abdominal and 3 pairs of back, to determine the best direction to obtain maximal EMG activity. The results showed that the rectus abdominis demonstrated maximal activity in trunk flexion, external obliques in lateral flexion, internal obliques in axial rotation and multifidius in extension. The latissimus dorsi and iliocostalis lumborum demonstrated maximal activity in two directions. The researchers concluded that to normalize the trunk

muscles examined would require a maximal contraction in at least six directions and three planes. Another study, Willett, Hyde, Uhrlaub, Wendel and Karst (2001), chose a repeated measures design to investigate abdominal activity resulting from five commonly prescribed strengthening exercises. It established that the “reverse curl” produced the greatest lower rectus activity, the “v-sit” and “reverse curl” the greatest external oblique activity, whilst the “trunk curl” with/without twist, “reverse curl” and “v-sit” produced similar levels of upper rectus activity. The findings supported the concept of abdominal exercises differentiating and activating specific muscle groups. Similarly, a study by Warden *et al.* (1999) compared the efficiency of an “abshaper” sit-up device to conventionally performed abdominal exercise. The main finding was that the abshaper resulted in significantly greater upper rectus activity, although the study does discuss the possibility that this may have arisen from biomechanical factors. There were, however, no significant differences found for lower rectus activity or external obliques.

3.3 Posture

The spine and muscles are part of a basic system, performing one of the primary functions of posture, which relate to maintaining the vertical alignment of body segments. This maintenance is often referred to as postural “stance”, which is basically the position that provides “a state of muscular and skeletal balance” (Bloomfield, *et al.*, 1994; p97). This position in turn helps counteract gravitational force resulting in the body’s COM being stabilised in relation to the ground and maintained within its BOS (Massion, *et al.*, 1996; p2; Bronstein, Brandt and Woollacott, 1996; p70). It is a unique component essential for both aesthetic purposes as well as for allowing the body to function

economically. According to Bloomfield *et al.* (1994; p95), posture is determined by factors such as bone structure, skeletal imbalance, injury, disease, activity levels, living habits, age and psychological state. Therefore stance would constantly change and adapt from birth, throughout an individual's lifespan (Slobounov and Newell, 1996; p185), with the intention of protecting supportive body structures against injury or deformity and fighting against the respective stresses continually being imposed. Bloomfield *et al.* (1994; p97) also states that a good postural stance from a sagittal perspective can be shown to encourage a vertical linkage of body segments in such a manner as to permit the line of gravity to "...pass through the anterior portion of the ear and then through the centre of each joint of the lower extremity". This would result in the minimal amount of mechanical adjustment being necessary to counteract gravitational effects in order to maintain this position. However, this "efficient" body segment alignment varies somewhat in description from Bronstein *et al.* (1996; p70) who suggests that "during standing the line of force lies in front of the vertebral, knee and ankle joint centres" and Nordin *et al.* (2001; p268) where the "line of gravity usually passes ventral to the centre of the fourth lumbar vertebral body". In the latter two examples, the line of gravity may not necessarily intercept the anterior part of the ear. As this would be an easily distinguished visual point of alignment, it would be more appropriate to use Bloomfield's definition for the purposes of this study. In addition, Bloomfield *et al.* (1994; p97) also considers poor alignment of segments to be a factor that could compromise balance, resulting in varying degrees of instability. In conjunction with the ongoing maintenance of incorrect posture, a poor stance would eventually result in the permanent stretching of some muscle groups and shortening of others. An example of this would be the rounded

shoulder postural position, so often seen in individuals who sit at a desk for long periods, where the anterior musculature (pectorals and anterior deltoid) have shortened and posterior (latissimus dorsi and posterior deltoids) lengthened.

“Static posture” (Masse, Gaillardetz, Cron and Aribat, 2000) relates to the right-left symmetry of the human skeletal structure whilst in equilibrium. In general circumstances, however, it tends to be assessed subjectively in an upright position from both a posterior or lateral viewpoint with the participant standing naturally against a variety of available grids (Bloomfield, *et al.*, 1994; p319). For a more detailed analysis relating to specific postural disorders, many other forms of imaging equipment have been designed and are available as screening tools. Nonetheless, the task of retaining this quiet standing stance is not entirely static as is suggested because it requires the “maintenance of certain relative positions of the body segments” along with “fine postural adjustments” (Slobounov, *et al.*, 1996; p185). This would mean that postural muscles need to be constantly activated in order to remain upright (Nordin, *et al.*, 2001; p268). Posture is an essential element in maintaining the body’s spatial orientation with respect to the environment, in addition to providing an accurate image of the position of body segments relative to each other (Massion, *et al.*, 1996; Horak and Kuo, 2000). Furthermore, with reference to upright posture, Slobounov and Newell (1996) have investigated spinal alignment in a standing position and compared it to an “inverted hand stance” or hand-stand stance. The outcome of this study displayed a greater motion in the COP data, partly due to the hands acting as a smaller BOS, resulting in greater instability of posture. COP data in this situation relates to centre of foot or hand pressure displacement, in

anterior-posterior and lateral directions, measured with a force platform. The upright stance itself also allows for optimal range of movement in the lower limbs and a unique position from where to operate the visual and vestibular sensory systems (Bronstein, *et al.*, 1996; p20). However, the necessity to maintain this head mounted position to gain input can be restrictive (Davis, Carpenter, Tschanz, Meyes, Debrunner, Burger and Allum, 2010).

Dynamic posture, on the other hand, is concerned with the body in motion and deals principally with all the postural components that stabilize the body along with prime movers contracted as a result of the intended move (Massion, *et al.*, 1996; p1). The key factors to consider in whole-body stabilization include BOS, ROM through the joints, muscle strength and stiffness (Horak, *et al.*, 2000; p267). The principal objective during movement would be to utilize energy-efficient strategies that co-ordinate body segments in such a manner as to accomplish the desired task or specific intention. This procedure needs to take account of equilibrium maintenance during movement by either stabilizing the centre of gravity (COG), in the event of arm or trunk movements, or shifting it towards the supporting limb prior to a leg movement (Massion, Mouchnino and Vernazza, 1995; p103). The imbalance that occurs by moving a segment, such as an arm, initiates the displacement of other segments in an opposing direction to compensate and regain the required position of equilibrium. With respect to trunk movements, Adams (1994; p125) suggested that a “safe” range of movement of the lumbar spine had been determined that, depending upon the degree of spinal mobility of the individual, would reduce the risk of back injuries from everyday activities. Spinal mobility for the purpose

of the current study may be defined as “...that quality in which vertebral structure maintain their anatomic relationships under all physiological loads” (Remer and Neuwirth, 1995; p1070). Furthermore, Adams (1994) suggested “...that a position of moderate lumbar flexion ...optimizes the distribution of stresses in the intervertebral discs [and is a] favourable option for absorbing the energy created during movement when the curvature ...varies during different phases of the gait” (p 126). This position would in turn reduce the degree of lordosis encountered in the upright stance, which then lessens the stresses placed on the apophyseal joints.

3.4 Balance

Postural stance requires constant monitoring and fine adjustment of the BOS and body position in relation to the environment. This process of maintaining balance, or a state of “equilibrium”, is achieved by integrating information from sensory receptors with central integration in the brain and motor response (Horak and Kuo, 2000; p267; Patla, 1996; p20; Perrin *et al.*, 1999; Maki and Ostrovski, 1993; Derave, *et al.*, 2002). The main sensory inputs are derived from proprioceptive, visual and vestibular systems. Once this data is integrated, it continuously determines whether balance is being maintained or lost (Abernethy, Kippers, Mackinnon, Neal and Hanrahan, 1997; p281). The first of these three inputs, proprioception, can be described as a sense of position and movement calculated from information gained within muscles, tendons, ligaments, joints and the skin. This “body perception” has a static element that provides a conscious orientation of one body part in relation to another, as well as a dynamic aspect that allows neuromuscular feedback about the rate and direction of the movement (Abernethy *et al.*,

1997). Next, sight is a dominant source of feedback signals and one of the most reliable. Visually gained spatial information tends to be rapid and reasonably accurate, particularly when combined with auditory information, although there is some question over the ability of these two systems to compensate fully in cases of reduced somatosensory input (Simoneau, Ulbrecht, Derr and Cavanagh, 1995). This combined information is required in order to allow hand-eye co-ordination to perform even the simplest of tasks. A study by Silfies, Cholewicki and Radebold (2003), investigating visual input on postural control of the lumbar spine, used a repeated measures ANOVA to determine changes of COP in unstable sitting. Findings showed COP displacements increased significantly without vision, although the study only included data from 13 healthy participants. Additionally, Vuillerme, Pinsault and Valliant (2005) found the availability of visual input allowed for individuals to suppress the destabilising effect of a foam surface during quiet standing. Furthermore, the management of sensory information can be influenced and managed through selected training. In relation to sport, a study looking at the balance control of expert fencers and pistol shooters (Herpin, Gauchard, Lion, Collet, Keller and Perrin, 2010; p162) established a "...differential effect on balance characteristics due to acquired specific motor skills".

In a standing upright stance, a displacement in the line of gravity changes the magnitude and direction of the moment acting upon the spine. To regain equilibrium following this change it is necessary to offset the moment by an increase in muscle activity causing "postural sway". The shape of an individual's spine, including the extent of habitual kyphosis and lordosis, will also be a contributory factor to the level of sway

recorded (Nordin, *et al.*, 2001; p268). It can generally be measured by three methods; namely body segment displacement, muscle activity or COP movements (Hasan, *et al.*, 1990; Okuzumi, Tanaka and Nakamura, 1996). Body segment displacement often requires subjective measurements against a posture grid. For muscle activity, measurements obtained are usually from the anterior tibial muscle and the gastrocnemius medialis using EMG. These would included short latency response, medium latency response and long latency responses (Perrin, *et al.*, 1999; Perrot, *et al.*, 1998). Finally, for COP measurements, the three components of force and the respective force-moments derived by means of a force platform electronically calculate the COP at each sampled interval. This results in a “stabilogram” and effectively the smaller the area covered by the COP the better the participant’s postural control. Until recently most studies considered COP to be stationary, however, Schumann, Redfern, Furman, El-Jaroudi & Chaparro (1995; p603) suggested that this may not be the case because the “statistical properties of COP change over time”. This is in agreement with a study by Carroll and Freedman (1993) who also found postural sway not to be a stationary process. Most studies in this area incorporate eyes-open and eyes-closed, to determine the contribution of visual input for controlling balance, as well as a double and single-leg stance. Often the data resulting from eyes-closed is inferior to that achieved with eyes-open (Perrin, *et al.*, 1999; Hasan, *et al.*, 1990).

Postural control and stability holds many implications for aging, with the elderly population together with younger children experiencing the greatest difficulty in maintaining balance (Streepey, *et al.*, 2002; Okuzumi, *et al.*, 1996). This in turn

contributes towards an increased risk of falling (Okuzumi, *et al.*, 1996; Perrin, *et al.*, 1999; p121). In fact, falls have been highlighted by Overstall, Johnson & Exton-Smith (1977) as the main cause of accidental death in the elderly. Perrin *et al.* (1999; p121) worked on the premise that inactivity promoted a decline in postural control and that the practice of physical and sporting activities could improve posture leading to a reduction in the number of falls experienced by the elderly. The findings from the study concluded that recent periods of practice had beneficial effects on postural stability, even for elderly people for whom exercise had not been a lifelong habit.

Finally, postural control is a topic accredited with growing interest as it encompasses a variety of implications relating to everyday functional aspects of human life (Derave, Tombeux, Cottyn, Pannier and De Clercq, 2002; p44). These aspects relate not only to the requirement to accomplish basic tasks efficiently and without pain, but also to more refined roles within areas such as rehabilitation or sports exercise performance (Hasan, Lichtenstein and Shiavi, 1990; p783). Literature regarding the use of sports to promote improvements in postural control is varied and inconclusive. A study by Fisher *et al.* (1998; pS45) concluded that “sports activities in general do not improve balance”. This is supported by Hugel *et al.* (1999), who suggested that training in classical ballet developed specific areas of balance that could not be utilized in everyday postural control. Conversely, there are the findings of Perrot *et al.* (1998; p133) who showed that judo training provided an “effective balance control by improvement of both motor performance and perception of the body in its surroundings”.

3.5 Low-Back Pain

Current western lifestyles, age and gravity influence postural development in such a manner as to give rise to a variety of injuries, in addition to a sliding scale of pain or discomfort. Alongside functional compromises attributable to an inherently unstable spine, such as weaknesses or imbalances in the abdominal musculature, this often leads to and indeed encourages the development of lower back pain (Porterfield, 1985; p271; Hodgkinson and Cartmell, 2003; p5; Warden, *et al.*, 1999; Willett, *et al.*, 2001). Low-back pain is often difficult for physicians to diagnose because of the variability of symptoms and lack of adequate tests, such as those that identify soft-tissue injuries (Smidt, 1994; p211). It should be acknowledged that postural recommendations applicable to individuals with a healthy back do not always apply to back pain sufferers who sometimes experience relief from exaggerated lordosis (Adams, 1994).

Chronic back pain can be described as “pain that has been present for longer than 6 months ... intermittent or constant ... vary[ing] in severity” that results in suffering to an individual, decline of their quality of life and expense to the NHS (Westwood, 1999; p193). Although back pain is the cause of numerous lost working days each year, Souhami & Moxham (2002; p1185) propose only a small percentage of individuals do actually seek medical attention. However, a Cochrane review by Schaafsma, Whelan, Ulvestad, Kenny and Verbeek (2010) concluded that physical conditioning programmes could have a small effect in reducing workplace absence as a result of back pain. Croft *et al.* (1998) investigated the incidents of back pain at two general practices in Manchester, UK. The research found that 90% of patients with back pain stopped consultations within

3 months, even though the majority of them would still be experiencing the pain and associated disabilities 12 months later. Additionally, by the age of 30, approximately 50% of the population would have experienced at least one episode of back pain. This would give substance to Carpenter & Nelson's (1999; p18) investigation proposing spinal disorders to be "the most frequent cause of activity limitation" in the under 45 age group. The cyclical problem they discovered, which is often referred to as the "deconditioning syndrome", was that due to their previous association of low-back pain with physical activity sufferers chose to avoid using their backs where possible. This reduced activity in turn leads to decreased joint mobilization, muscular strength, endurance and so on, thereby creating further avoidance of activity (p20). In addition, as about 50% of back injuries for which compensation claims are involved arise from the task of manual lifting, there is the suggestion that workers with insufficient strength lifting heavy objects are more likely to be at a greater risk of injury (Buckwater, *et al.*, 2000; p778). It would therefore be advantageous to look further into posture with the ideal of strengthening "core" muscles or addressing spinal imbalances through exercise, in order to reduce musculoskeletal symptoms such as back pain. This would be in line with the National Institute for Health and Clinical excellence (NICE) guidelines on the early management of persistent non-specific low back pain (NICE, 2009; p2), which suggests promoting self-management of back pain with exercise as one of the various treatment options on offer.

3.6 Rehabilitation

Muscle weakness, due to a sedentary lifestyle and insufficient physical activity, may contribute towards the occurrence of low-back pain (Smidt, 1994). Its treatment would therefore necessitate incorporating strength and endurance exercise specifically for the musculature of the trunk. In addition, the NICE guidelines (2010;p5) based on “best available evidence”, suggest advising people with back pain to remain physical active with exercise programmes that could include elements of aerobics, muscle strengthening, postural control and stretching. The effectiveness of these regularly administered exercises, along with comparisons of exercise variations, is one focus area in this field of research. A Cochrane review by Choi, Verbeek, Tam and Jiang (2010) investigated the effectiveness of exercise for preventing a recurrence of back pain or associated disability. Their review of nine studies concluded there was moderate quality evidence that post-treatment exercises could reduce the rate and number of back pain recurrences, post-treatment in this instance was defined as exercise treatment following an episode of back pain. Physiotherapists prescribed and supervised the majority of treatments discussed within the review. One study by Sherman, Cherkin, Erro, Miglioretti and Deyo (2005), investigated the effectiveness of a 12-week exercise programme for individuals with CLBP compared to their usual care and compared a yoga group (n = 36), a conventional exercise group (n = 35) and a self-care book group (n = 30). Results showed the back-related function in the yoga group to be significantly better than the other two groups and concluded yoga was the more effective treatment for improving function and reducing CLBP. A paper by Posadzki, Lizis, and Hagner-Derengowska (2011) reviewed four studies related to trials that used Pilates to treat CLBP. The authors concluded that

Pilates produced better therapeutic results than standard care, but this was inconclusive due to a limited evidence base and small sample sizes. Smidt (1994) highlighted four studies between 1958 and 1990 that reinforce the limited availability of research along with variation of test parameters and findings. The first used sit-ups and back extensions over 12-weeks with a progressive increase in resistance. 89% of participants encountered some relief from back pain but it was noted that the lack of a control group diminished the reliability of the results. The second study, using isometric flexor exercises, reported an overall 22% gain in trunk strength. The third emphasised the idea that strength gains in the first few weeks may be attributable to external factors such as a reduction in fear or anxiety rather than physical changes to the muscles. The last study found no differences in strength gains, possibly due to the higher levels of back pain encountered within the group. Furthermore, Warden *et al.* (1999) suggested it is the endurance of the rectus abdominis and external obliques rather than their strength, that has been shown to discourage the occurrence or re-occurrence of back injuries. Finally, the NICE guidelines (2010; p106) also recommended there was no evidence that exercise administered on a one-to-one basis for back pain was better than group exercise formats.

3.7 Conclusion

The literature reviews within Chapters 2 and 3 have provided a fairly extensive background to both mind-body treatment interventions and CLBP. Chapter 2 started by discussing the research behind yoga, tai chi, Pilates, Feldenkrais and BodyBalance. It particularly highlighted findings that could have been used to support selected claims outlined within the BodyBalance promotional material. This was followed by an

explanation of the route studies took within the thesis and why their aims were adapted as the research progressed. Next, chapter 3 sought to provide information on research relating to the physiology of the spine, in addition to biomechanical aspects concerning balance and posture. This then continued to provide a general explanation of back pain and the connection of exercise to its rehabilitation. With all the basic literature discussed, we now advance into the first of three investigations.

Chapter 4

**A Comparison of the Physiological and
Psychological Responses in Adults: A 12-Week
BodyBalance Training Programme**

2005

School of Human and Life Sciences
Roehampton University

Study 1 – A BodyBalance Investigation

“Basic research is what I am doing when I don’t know what I am doing.”

Weber, 1973

4.1 INTRODUCTION

Demand for the pre-choreographed programmes offered by Les Mills International has grown dramatically since the company’s inception in 1997. From a weights programme, designed initially for use by its own seven clubs in New Zealand, it has expanded first into Australia and then internationally so that the company now has “licensees in 67 independent countries” attracting an estimated 4 million weekly attendances. A press release posted on their website in August 2006 states “Les Mills passes 10,000 club milestone” which means it has encountered a growth of approximately 11% in the period from November 2004, thus showing the continuing interest for the product (Les Mills, 2006a). On the same site, an earlier press release (Les Mills, 2004a) also analysed the popularity of each programme based upon the number of clubs it was offered at, with BodyPump leading the way (8,200 clubs) followed by BodyCombat (5,500), BodyBalance (3,941), BodyStep (2,920), BodyAttack (1,985), RPM (2,158) and finally BodyJam (1,642). In September 2009, the website announced it had grown to a licensee base of 13,000 health clubs, an increase of yet another 40% over 3 years, now attracting an estimated 6 million attendances (Les Mills, 2009). Again, the increase in demand for each of the respective workouts contributes towards the company’s overall growth and success. In terms of worldwide distribution if we consider BodyPump for example, which is the most popular Les Mills programme in 2006, the number of

licensed clubs increased to 9,072, with the largest consumer being Brazil, followed by the UK, the US and then Australia. This level of international success has accorded Les Mills the title of the “world’s biggest producer of branded fitness classes” having already been awarded the Service Exporter of the year in 2005 by New Zealand Trade & Enterprise Export. In 2004, its goal was to achieve 10,000 licensed clubs and it has now accomplished this. Its next target is 25,000 club licensees by 2015 (Les Mills 2006a). This would give it tremendous potential to influence the fitness market, workout trends and the health of the nations that utilise their products. One underlying question raised from a research perspective would be whether these seven programmes actually deliver the results suggested. This is largely because there has been minimal direct investigation into the individual disciplines to date and Les Mills International itself commissioned most of the studies in existence that substantiate their proposed claims. Despite the shortage of specific studies, there is a wealth of literature available within exercise-related research that adds credibility to the arguments promoting the effectiveness of BodyPump, BodyCombat, BodyAttack and BodyStep. Most of this can be found within studies under headings such as strength training, martial arts, circuit training and step. However, there is a distinct lack of quality investigations within the same to support the mind-body programme of BodyBalance.

BodyBalance, described above as the third most “popular” club license purchased in 2004, is also credited with being the fastest growing programme of 2004. The benefits of the workout are founded upon the results of numerous studies conducted into yoga, tai chi, Feldenkrais and Pilates, irrespective of how poor the study design or how weak the

link between BodyBalance and the exercise format for the factor in question. Literature produced and distributed for promotional purposes suggests that BodyBalance will “...improve joint flexibility and range of movement, increase core strength, improve cardiovascular function, burn calories, reduce stress levels, provide a sense of well being and calm and focus the mind...” (Les Mills, 2006b). This leaflet also suggests that these benefits can be derived from attending just one class a week, although three per week is the “ideal”. The current study is aimed at testing the validity of selected claims to see if they are of any value to a participant wishing to improve their health.

4.2 LITERATURE REVIEW

A BodyBalance class generally consists of forty-five minutes of “simple but challenging exercises”, namely a tai chi warm up superseded by various yoga moves to enhance flexibility and balance followed by Pilates or Feldenkrais type exercises to enhance posture and core strength. At the end remains some ten minutes of partially choreographed relaxation and meditation (2006c). Current and historical promotional literature have suggested a variety of physiological, psychological and biomechanical benefits could arise from participation in workouts of a similar nature, so it is therefore these aspects that are of interest to this primary investigation.

The first area to be discussed in connection with the advertised claims of BodyBalance concerns measures of anthropometry and body composition. Within the US, as in other western countries, obesity as defined by BMI is increasing. In 1994 Kuczmarski, Flegal, Campbell and Johnson reported this as having reached 33.4% of all

adults aged 20 years or older. Although mind-body exercise is not considered a means of expending high numbers of calories (Clay, Lloyd, Walker, Sharp and Pankey, 2005), thereby resulting in dramatic weight loss, there is the possibility of some influence particularly in terms of body composition and girth measures. This would therefore be the springboard for BodyBalance claims such as “...without dieting, and without sweating away in a frantic aerobics class, you will look a size smaller...” (Les Mills, 2000). To substantiate this are the results of studies such as Lan, Lai, Wong and Yu (1996) who found a significant reduction in the skinfold measures of elderly tai chi practitioners and Bera and Rajapurkar (1993) who established significant reductions in skinfold as well as waist and hip circumference measures after a year of yoga exercise. In addition, Wilmore, Despres, Stanforth, Mandel, Rice, Gagnon, Leon, Rao, Skinner and Bouchard (1999; p346) concluded their investigation by intimating “...a short term exercise intervention can induce favourable changes in body composition”. Wilmore *et al.*, however, had used cycle ergometers as the means of training rather than mind-body. These results are also in conflict with the findings of others investigations such as Jago *et al.* (2005) and Segal *et al.* (2004) who found no statistically significant changes in body mass, BMI or circumference measures following Pilates training.

Other areas, often of curiosity to researchers into forms of exercise, are the effects in changes of BP and lung capacity. This is also applicable in respect of the second area of BodyBalance to be investigated, which utilises the principle of “breathing” taken from yoga and tai chi, but the findings could be somewhat diverse and fall into one of three categories. In some studies, no significant changes were noted for either SBP or

DBP. Two such examples (Gutman, Herbert and Brown, 1977; Bowman, Clayton, Murray, Reed, Subhan and Ford, 1997) used an elderly population who followed yoga or a Feldenkrais programme. The results were analysed and compared against a more conventional exercise form, such as aerobics, after an intervention period of six weeks. In other cases (Sung *et al.*, 2000; Murugesan *et al.*, 2000) the results indicated a significant reduction in SBP with no significant change to DBP following yoga intervention. In these instances the purpose was to assess the effects of interaction for both normotensive and hypertensive participants. In the remaining studies, the effects of intervention displayed a significant reduction in both SBP and DBP after 12-weeks of tai chi intervention, at 3-4 sessions per week, or after a yoga relaxation programme (Thornton *et al.*, 2004; Young, Appel, Jee and Miller, 1999; Brownstein and Dembert, 1989). There appears, therefore, to be no conclusive expectation as to the effects of BP following this style of exercise but it does appear to be somewhat dependent upon the duration and frequency of the intervention programme as well the type of workout selected. Likewise, the findings of a selection of yoga studies investigating pulmonary function were also variable. No significant changes were detected in two investigations of yoga on asthmatic patients that incorporated a control group (Vedanthan, Kesavalu, Murthy, Duvall, Hall, Baker and Nagarathna, 1998; Fluge, Richter, Fabel, Zysno, Weller and Wagner, 1994). There were, however, significant improvements in lung function measures investigating both asthmatics and college students where no separate control groups were assigned (Jain *et al.*, 1991; Birkel *et al.*, 2000; Madanmohan *et al.*, 1992). The inclusion of and the validity of studies without a control group are therefore another factor to be given consideration.

A further benefit claimed by BodyBalance is its ability to focus “...on strong core (abdominal and back) stability.... [and] improve joint mobility, flexibility and your body’s range of movement...” (Les Mill, 2000). It is therefore of interest to this study to consider available research on the components of fitness underlying mind-body, namely cardiovascular, strength and flexibility. The first point to highlight is that mind-body exercise may not be the first choice for those participants wanting to improve their cardiovascular fitness. Despite this, it can exert a sufficient physical load on the cardiovascular system to produce changes in the heart rate (HR) and BP “comparable” with a brisk walk at 6km/hr (Jin, 1992). A study by Hong *et al.* (2000) showed significant improvements in both resting HR and exercise HR for 28 male tai chi practitioners. An earlier study on a group of asthmatics by Jain *et al.* (1991) also found a significant increase in “exercise capacity” as measured by a 12-minute walk test. However, a study by Blumenthal that used the yoga and flexibility as a control, showed no significant changes in cardiorespiratory fitness for this group. Next, with regard to strength, a number of measures within mind-body research have been determined using a handgrip dynamometer. In two studies on carpal tunnel syndrome and osteoarthritis, only one showed a significant difference in handgrip strength after 8-weeks of a yoga type regime (Garfinkel *et al.*, 1998; Garfinkel *et al.*, 1994) although Madanmohan *et al.*, (1992) also showed a significant increase in hand grip strength after a 12-week yoga programme. Other studies following 12 weeks of tai chi exercise on older adults have also brought about significant improvements in strength for the abdominal region and in the knee and ankle flexors and extensors (Song *et al.*, 2003; Choi, Moon and Song, 2005). Finally, most research conducted to assess flexibility has been on older adults.

Two out of three studies on older tai chi practitioners found a statistically significant improvement in measures of flexibility (Hong *et al.*, 2000; Choi *et al.*, 2005; Song *et al.*, 2003) as did one study assessing hip extension following Iyengar yoga on the elderly (DiBenedetto, Innes, Taylor, Rodeheaver, Boxer, Wright and Kerrigan, 2005). Overall, existing research on the mind-body workouts underlying the BodyBalance programme does seem to indicate the possibility of improvements in the components of fitness that exists to practitioners.

In terms of posture and balance, the BodyBalance marketing department has suggested this workout “...encourages good posture...improve[s] coordination and balance...” (Les Mills, 2000). This proposition would be in keeping with a study by Gauchard, Jeandel, Tessier and Perrin (1999) who concluded that proprioceptive exercises like yoga, rather than cycling, swimming and jogging, would appear to have the best impact on balance control. Tai chi, in particular, has been shown to significantly improve proprioception and maintain balance control, especially in the older population (Hong *et al.*, 2000; Li *et al.*, 2001; Maki *et al.*, 1993; Song *et al.*, 2003; Xu *et al.*, 2004). Likewise, participating in Feldenkrais has been shown to produce a significant improvement in balance in an upright position (Kendall, Ekselius, Gerdle and Soren, 2001; Kaesler, Mellifont, Kelly and Taaffe, 2007), which is sometimes labelled [as] “postural stability” (Kaesler *et al.*, p37). However, with the discipline of Pilates, it is suggested this enhancement is the result of the effect upon pelvic posture, musculoskeletal structure of the spine and structure or muscle tone of the “abdominopelvic cavity” (Muscolino *et al.*, 2004; p15).

Finally, the psychological effects of mind-body exercise are often associated with a sense of calmness and positive mental health. As such, Les Mills (2000) argues that BodyBalance acts as "... a natural remedy to stress... [and] will improve general well-being". Popular instruments often used to assess levels of stress, anxiety and mood states include the STAI and the POMS alongside many others. In the past there have been numerous investigations connected to resistance training or cardiovascular work that has resulted in a reduction in state-anxiety as measured by the STAI (Garvin, Koltyn and Morgan, 1997; Hale, Koch and Raglin, 2002). The same significant decrease in state-anxiety following mind-body interventions such as relaxation or quiet rest, has also been noted (Dekro, Ballinger, Hoyt, Wilcher, Dusek, Myers, Greenberg, Rosenthal and Benson, 2002). In terms of mind-body type programmes, Feldenkrais and tai chi have shown a positive influence on state-anxiety both over the duration of a single lesson or a course of treatments (Kerr *et al.*, 2002; Jin, 1992, Johnson *et al.*, 1999; Kolt *et al.*, 2000). There is, however, the prospect of the stress reducing capability of the programme being dependent upon the participant's age and gender (Bond, Lyle, Tappe, Seehafer and D'Zurilla, 2002). Research using the POMS, or scales validated against POMS, shows that yoga and Feldenkrais significantly improve mood (Manocha, Marks, Kenchington, Peters and Salome, 2002; Netz and Lidor, 2003; Wood, 1993) although obviously this is not always the case (Oken, Zajdel, Kishiyama, Flegal, Dehen, Hass, Kraemer, Lawrence and Leyva, 2006). Again, this relates to changes that occur over the duration of treatment regardless of whether it is one solitary session that is assessed or a series of single sessions over the course of the intervention period (Berger *et al.*, 1992; Berger *et al.*, 1988). The total mood disturbance (TMD), created by stressors and calculated from the

separate subgroups of the POMS, have also been shown to be significantly reduced following a tai chi workout. (Jin, 1992). In addition, the assessment of “general well being” can be determined using some form of psychological “health questionnaire”. Studies utilising tai chi, Feldenkrais and yoga have all incorporated the use of these self-report type questionnaires that subjectively measure symptoms relevant to health and well-being. The findings from most of these show a significant improvement (Lowe, Breining, Wilke, Wellmann, Zipfel and Eich, 2002; Oken *et al.*, 2006; Yeh, Wood and Lorell, 2005).

4.3 METHOD

Participants

A cluster of 40 healthy adults, 8 male and 32 female, participated in the study. Recruitment of these participants was through a variety of channels (see appendix i - iv). The majority of those selected arose out of inquiries to 3,200 leaflets outlining the study that were systematically distributed to houses surrounding the campus where treatment took place (n = 30). The remainder was gathered in response to an advertisement in the local newspaper (n = 2), posters on the college notice boards (n = 4) and a bulletin on the university web site (n = 4). Respondents were forwarded more comprehensive details regarding the nature, design and purpose of the study along with a “Health and Lifestyle Questionnaire” (HLQ) to complete (see appendix v – vii). This requested in-depth information about their medical status and exercise regime. Exclusion criterion applied to: (a) individuals who were currently, or had within the preceding 3-month period, participated in mind-body programmes; (b) were not within the specified age band of 18-

65 years; (c) had suffered from any medical conditions that would influence the integrity of the results or compromise safety during BodyBalance treatment. Volunteers were randomly assigned to either a control lecture group (n = 20) or the exercise intervention group (n = 20). The method of assignment required names to be divided between two boxes based upon gender and then alternately allocated to each group via a blind draw from each box; this resulted in 4 men and 16 women per group. Six of the forty participants did not complete the study for the following reasons. One male from the control group and two from the exercise group withdrew due to work commitments. One female from the control group “...felt there was nothing to be gained...” and the other two females, one from each group, incurred an injury or illness that prevented them from taking part. The physical characteristics of the remaining participants (n = 34) are listed in Table 1.

Table 1 – Physical characteristics of participants who completed study 1 (Mean ± s.d.)

GROUP	PARTICIPANTS (n)	AGE (Years)	HEIGHT (cm)	WEIGHT (Kg)
EXPERIMENTAL	17	43.8 ± 9.1	166.0 ± 8.3	71.5 ± 13.4
CONTROL	17	40.8 ± 12.9	167.5 ± 8.2	75.0 ± 17.4
TOTAL	34	42.3 ± 11.1	166.7 ± 8.1	73.3 ± 15.4

All participants provided written informed consent before participating in the study (see appendix x), which had prior approval by the University Ethics Board. The informed consent included the rights of the participants to withdraw from the study at any stage along with the terms of the honorarium that provided control group participants with an 8-week leisure centre pass upon completion.

Experimental Procedure

The study took place at Whitelands College, Roehampton University in London. Upon allocation to experimental or control groups, participants received a timetable of events in addition to a 3-day diet sheet (see appendix viii, ix, xi). This requested information on both current dietary intake and exercise regime, and required completion prior to commencement of the intervention process. All participants were asked to maintain their current physical activity and regular dietary habits. The timetable scheduled baseline evaluation tests for weeks 1 and 2, BodyBalance intervention treatment or control group health lectures from weeks 3 to 14 and post-intervention tests for week 15. Prior to testing, individuals had the opportunity to clarify any concerns they may have about the study or testing procedure. At both preliminary and post-intervention sessions, each participant undertook a battery of tests carried out in a predetermined order aimed at establishing physiological, anthropometric, psychological and biomechanical measures (see appendix xiv). The parameters included in the series were BP, pulmonary function, flexibility, back strength, aerobic power, height, body mass, girth, body composition, state-anxiety, mood, balance and posture. Pre-intervention assessments took the form of individual 120-minute sessions conducted at the laboratory in the Sports Performance Assessment and Rehabilitation Centre (SPARC) at Whitelands College. Re-testing of participants successfully completing the 12-week intervention utilised the same battery of assessment measures as at baseline (see appendix xiii). Additional psychological questionnaires administered during the intervention period at specified lectures or exercise classes were the POMS-A and STAI-Y1. Outlined below are the contents of the test battery.

Measurements

Anthropometry and body composition

Body Mass and Height

SECA 705 digital scales (Vogel and Halke, Hamburg) were used to determine the mass of the participant to the nearest 0.1kg. Likewise, a Holtain (Dyfed) wall-mounted stadiometer was used to measure height to the nearest 0.1cm. Participants were required to wear the same light clothing with bare feet for both testing sessions. Measures taken with these instruments have been shown to have a high degree of reliability and validity in adults (Geeta, Jamaiah, Safiza, Khor, Kee, Ahmad, Suzana, Rahman and Faudzi, 2009).

Girth

A Holtain anthropometric tape was used to measure the circumference twice at six standardised sites on the body in rotation according to the landmarks detailed in Heyward (1997). These sites comprised of the chest, waist, hips, right thigh, right calf and upper portion of the right arm. Participants stood in an erect but relaxed stance whilst the tape was applied snugly at right angles to the long axis of the bone using a cross-handed technique (see appendix xv). After recording the results to the nearest 0.1cm, the two readings for each anatomical site were averaged. These six averages were then added together to provide a single girth measure. Reliability of waist circumference measures, recorded to the nearest 0.1cm with a measuring tape, has been shown to be reliable in adults over 18 years of age (Geeta *et al.*, 2009).

Body composition

The Durnin & Womersley equation was used to establish skinfold to the nearest 0.1 mm on the right side of the body. Assessments were taken with Harpenden Skinfold callipers HSK-BI (British Indicators, West Sussex) at the biceps, triceps, suprailiac and subscapular sites. A Holtain anthropometric tape helped to determine any necessary midpoints that would assist accurate measurement. Skinfold readings were repeated twice in rotation and the data from each site averaged. The resulting information, once input into a Viglen (Contender P5/120) PC, analysed body composition using a software package developed by Roehampton University's SPARC. The basis of the software was the skinfold equation attributed to Siri (1956). The formulae used to assess body composition and examples of related calculations can be viewed in appendix xvi. Skinfold measurements have been predicted to lie within 5% of hydrostatic weighing, which has a test-retest reliability coefficient above $r = 0.94$, (McArdle, Katch and Katch, 1996; pp553-557).

Physiological

Blood Pressure

BP assessment was performed after a 5-minute seated rest interval using a standard Boso-medicus automated sphygmomanometer (Bosch & Sohn, Jungingen) to evaluate both diastolic and systolic readings. The unit itself operated once the cuff, placed around the left arm just above the elbow, picked up pressure variations in pulse waves and transmitted them to a microprocessor for evaluation. A second reading, which was taken 2 minutes later, allowed for an average of the two diastolic and the two systolic

measures to be calculated. Repeated measurements improved the reliability of results (Beevers, Lip and O'Brien, 2001).

Lung Capacity

Pulmonary function was measured with a Vitalograph-compact spirometer (Vitalograph Limited, United Kingdom) and used to determine forced vital capacity (FVC), inspiratory vital capacity (IVC), forced expiratory volume in the first second (FEV_1) and forced expiratory ratio between FEV_1 and FVC ($FEV_1/FVC\%$). The accuracy level of the unit to record gas volumes and flows at ambient temperature and pressure was given as within 3%. The researcher initially demonstrated the process for both the expiratory and inspiratory tests following which the participant performed a practice trial assisted by an instruction sheet that was available throughout for reference (see appendix xvii). The protocol required the participant to stand and to hold the flow-head such that the lips could comfortably surround the disposable mouthpiece. Verbal instructions given whilst performing the test encouraged maximisation of respective expiratory and inspiratory breaths. There were three trials conducted for each test and the "best" result recorded for analysis.

Step Test

The 3-minute step test used to assess cardiovascular ability adhered to the protocol issued by the YMCA (American College of Sports Medicine, 1995; p73). Following a demonstration and practice run covering aspects of technique and safety, the participant was required to step up and down on a 12-inch high step platform. A

metronome set to 96 beats per minute dictated the speed of movement and the participant was encouraged to perform continuously at one-step per beat. A stopwatch, started upon first foot placement on the platform, monitored the required time of 3-minutes. The researcher informed participants as each minute elapsed and when the final fifteen seconds remained. A heart rate monitor (Polar Sport Tester, Finland) attached around the chest detected the heart rate which was recorded upon completion of the test. Reliability of a similar sub-maximal step test was shown to be reliable on a test-retest basis (Buckley, Sim, Eston, Hession and Fox, 2004).

Back Strength

The test to determine the isometric strength of the back adhered to the protocol listed within the Takei Test Manual accompanying the “back dynamometer” (Takei & Company Limited, Tokyo). The measuring accuracy of the unit was given as ± 3 kgf in 150 kgf. The participant was required to stand on the back dynamometer footplate, holding a bar attachment with a natural overhand grip. From a forward flexed starting position of 30° , they were then to return to an upright stance without using any knee flexion, pulling the handle up gradually. The researcher demonstrated the move prior to testing and the participant performed a practice trial to familiarise themselves with the equipment. The three trials conducted were interspersed with one-minute rest intervals. The Takai portable back dynamometer has shown high test-retest correlations for back strength ($r=0.91$) (Coldwells, Atkinson and Reilly, 1994).

Flexibility

Modified sit-and-reach test

The modified sit-and-reach test protocol, as described by Hoeger (1989), was used to assess trunk and hamstring flexibility. The equipment required was simply a 12-inch high sit-and-reach box, which was placed close to a wall, in conjunction with a metre rule pointing toward the participant and at a right angle to them. The participant sat on the floor with their buttocks, shoulders and head in contact with the wall, both feet placed against the front surface of the box and arms outstretched in front resting on the superior surface of the box. The zero marking on the yardstick was then set at the point where the participant's fingertips ended. The objective was to slide the hands along the top of the yardstick, in a slow and controlled manner, holding them for two seconds at the furthest attainable point. The best of three trials was noted. A test-retest reliability coefficient of $r = 0.83$ has been reported in existing literature (Hong *et al.*, 2000).

Range of Motion

A clinical goniometer (Medical Research Limited, Leeds), given as accurate to $\pm 1^\circ$, was used in this study to determine levels of trunk flexibility; namely hip flexion, hip extension, hip abduction and lateral flexion. All trials called for the pelvis to be held stationary by the researcher thus preventing unwanted rotation or tilting and each test was preceded with the goniometer being accurately aligned to zero whilst resting on a horizontal surface.

The three tests to assess hip joint ROM required that the participant lay on a physiotherapy bench with knees fully extended. The first of these measures, hip flexion, entailed the participant lying supine on the bench. The clinical goniometer was placed just above the patella on the right leg and the participant was asked to flex at the hip whilst maintaining the left leg in contact with the table. The thigh on the active leg was brought as far as possible towards the trunk, whilst flexing the knee in order to maximise ROM. The goniometer was held in place by the experimenter during the movement and ROM read from it upon completion. The second measure, hip extension, called for the participant to lie prone with a goniometer placed on the right hamstring, just above the knee joint. They were then required to raise the leg in a controlled manner, avoiding knee flexion, and to ensure their pelvis at the level of the anterior superior iliac spine (ASIS) did not lose contact with the bench. The third measure, hip abduction, required the participant to lie on their left side with shoulder, hip, knee and ankle in alignment and the goniometer resting just above the knee joint on the lateral aspect. With maximal straight leg abduction of the right limb, performed with a flexed foot and toes pointing forwards, the reading taken was at the point just prior to where tilting or rotation of the pelvis started to occur. The final test, to assess thoracic and lumbar lateral flexion, involved the participant starting from an upright stance with arms hanging down alongside the body. A goniometer was placed vertically upon their right shoulder so that its base rested across the bony landmark of the acromion process. The participant slid their right hand down the lateral aspect of the right thigh as far as possible; again without any pelvic tilt, pelvic rotation or trunk movement in the sagittal plane. All measures were repeated three times and the average used to provide four measures of flexibility. Test-

retest measures of ROM have been shown to be reliable (Gabbe, Bennell, Wajswelner and Finch, 2004; Lariviere, Gagnon and Loisel, 2000).

Biomechanical

Balance

Static postural stability assessment was performed using a force platform (Kistler type 9281 B11, U.S.A.) and involved a series of Romberg single and double-leg stance test conditions with eyes both open and closed (Whitney, 2004). Romberg tests are well documented within balance literature with good test-retest reliability (Wiksten, Perrin, Hartman, Gieck and Weltman; 1996; Mientjes and Frank, 1999). These four conditions each had a ceiling of ten trials, interspersed with 30-second rest intervals, from which the participant had to attempt to complete only three. Initially, the researcher established the participant's dominant leg, as this would be the one used for all single stance tests at baseline and post-intervention. The criteria to determine this involved a football, rolled along the floor towards the participant, impulsively kicked back to the researcher. The dominant leg was the one used most frequently by the participant out of three consecutive trials. Next, consistent foot placement on the platform was encouraged by tracing the outline of the participant's dominant foot, along with both feet for the two-footed stance, onto graph paper and attaching it to the centre of the force platform.

Each trial lasted for 30-seconds during which the participant had to stand barefoot and upright on the force platform with arms folded across the chest and hands placed upon the opposite shoulder. The participant was directed to stay as motionless as

possible. Recording of data commenced with a five-second countdown once a comfortable starting position was attained. This first condition consisted of a two-legged position with feet together and eyes focused upon a circle, 3cm in diameter, placed nine feet directly in front of the participant at eye level. Subsequent conditions included a two-legged stance with eyes closed, a single-legged stance with eyes open and finally a single-legged stance with eyes closed. The opportunity was available before the last condition for the participant to practise standing on one leg with both eyes closed. Criteria for termination of a trial by the researcher were if either hand lost contact with the respective shoulder, if a weight-supporting foot moved, if the eyes opened within the closed-eyes condition or if the raised leg in a single-legged stance touched the supporting leg or the ground.

In order to minimise interference, the 600mm x 400mm force platform rested on a Kistler mounting set within a 5-meter square block of cement. The quartz piezoelectric transducers in each corner facilitated the gathering of COP data for the three force components on the medial-lateral, anterior-posterior and vertical axes (F_x , F_y and F_z) along with their respective force moments (M_x , M_y and M_z). Analogue signals detected from the platform were amplified by an 8-channel Kistler 9865 amplifier, which was interfaced by an analogue to digital converter (ADC) to a Tiny computer. Data were filtered using a low-pass Butterworth filter with the cut-off frequency at 10Hz. The sampling frequency, set at 50Hz, gave rise to 1,500 data points during the 30-second trial. To reduce sampling error, only the middle 1,000 data points, depicting 20-seconds of data per trial, were analysed using Bioware version 3.22 software. The average data for each

parameter, evaluated from its set of three trials, formed the basis of calculations to determine sway path length per second, average radial displacement, area per second and mean frequency. Romberg's quotient, which distinguishes the impact visual contribution has on sway, was also established. All respective formulae can be found in Appendix xviii.

Posture

Static posture was assessed from three still photographs taken using a Sony Cybershot digital camera (model DSC-P12, Sony Corporation, Japan) that was mounted on a tripod and placed at a distance of nine feet from the participant. The alignment of body segments viewed from an anterior perspective required markers to be adhered to both left and right sides of the body at the following locations: the earlobes, just below the acromioclavicular joint, the anterior superior iliac spine (ASIS), the patella centre and the ankle at the level of the lateral malleolus. Additional marker placements, on the episternal notch and the umbilicus, assisted analysis in the frontal plane. The first of the 640 x 480 pixel images, recorded for calibration purposes, involved the participant holding a 30cm tall card against the left ear. Participants were requested to stand barefoot on a marked platform in a comfortable upright stance with their head level. The next anterior image used an identical posture but the arms could hang comfortably at the sides of the participant's body. The photograph to assess alignment from a lateral perspective involved five markers attached to the surface of the right side of the body as follows; external auditory meatus, head of the humerus, greater trochanter, centre of the knee level with the midline of the patella, and the ankle just in front of the lateral

malleolus. The participant was required to stand sideways on, facing the left so all markers were displayed and where necessary asked to move the lower right arm to expose the trochanter marker. The resulting data, input into a Sony VAIO notebook computer (Sony Corporation, Japan), was analysed using Posture Pro 5.0 software (Ventura Designs, USA).

Psychological

GHQ

The 12-item General Health Questionnaire (Goldberg and Williams, 1991) was administered for completion upon arrival at both the first intervention class in week one and the final testing session. This questionnaire has been shown to have a high test-retest reliability (Goldberg *et al.*, 1991; p25). It is designed to question how the participant felt their health had been in general over the few weeks preceding completion and used a 4-point Likert-type scale of 0 to 3 to rate each of the twelve statements accordingly (see appendix xix). The maximum cumulative score gained is therefore 36 and the higher the participant's score, the more the negative symptoms are emphasised. As with all questionnaires used in this study, it followed the administration design advocated in the respective manual.

STAI

The Stait-Trait Anxiety Inventory for Adults (STAI) has been extensively validated (Spielberger, Gorsuch, & Lushene, 1970) and is widely used to investigate anxiety within exercise-based research (Rostad & Long, 1996). The shortened 20-item

“trait” aspect of the Inventory, the STAI – Y2, establishes how the individual feels on a “general” basis in response to a series of statements (see appendix xx). Administered upon arrival at both testing sessions, statements were rated using a 4-point Likert scale from 1 to 4 indicating “almost never” to “almost always”. Instructions for completion were clearly outlined at the head of the question sheet and required participants to circle the most appropriate answer. In a similar manner, participants were presented with a 20-item “state” anxiety questionnaire (STAI – Y1) upon arrival to BodyBalance on three different occasions: the first class in weeks 1, 6 and 12. This inventory encouraged the participant to explore how they identified with certain physical and mental areas of their life at that specific moment in time. As state-anxiety easily fluctuates, the questionnaire administered again upon completion of the relaxation component at the end of each respective class, determined the short-term effects arising from individual session participation. The scoring system was the same format as for the STAI –Y2.

POMS

The Profile of Mood States (POMS; McNair, Lorr & Droppleman, 1992), like the STAI, is an instrument often used within exercise and anxiety literature. The twenty-four item version of this measure, the Profile of Mood States –Adolescents (POMS–A; Terry, Lane, Lane & Keohane, 1999), was used to assess the six subscales of tension, depression, anger, vigour, fatigue and confusion (see appendix xxi). Internal consistency for the POMS – A was reported (Terry *et al.*, 1999) to be high and test-retest coefficients ranged from 0.26 to 0.53, which could be considered appropriate due to the transient nature of the variable. Each item, scored using a 5-point Likert scale that ranged from 0

to 4, indicated a level between “not at all” to “very much”. The Total Mood Disturbance score was then calculated by weighting vigour as a negative factor and deducting this value from the sum of the remaining five states (McNair *et al.*, 1992, p6). Validation of the POMS-A involved 3,361 participants between the ages of 12 and 39 years (Lane, 2001). In addition, it had demonstrated concurrent validity through correlations between POMS-A scores with previously validated inventories (p120).

Activity

Experimental Group

For the twelve weeks of intervention, weeks 2 to 13 of scheduled events, the experimental group was required to attend BodyBalance classes in the college gymnasium. Each class lasted for 60-minutes, although additional time was required on the three occasions that psychological questionnaires had to be completed. Classes took place at lunchtime on Mondays, Wednesdays and Fridays and a different qualified BodyBalance instructor was recruited for each of the three days (see appendix xii). The instructors taught identical choreography based on BodyBalance 25 (Table 2) so that each session was the same in terms of the movement components but varied due to instructor personality. Appropriate Public Liability insurance and music licences were provided and the researcher obtained written confirmation from “Fitness Professionals” to perform the BodyBalance on unlicensed premises.

The BodyBalance CD consisted of 11 music tracks, ranging from 2:05 minutes in length for the meditation track to 6:30 minutes for standing strength (see appendix xxii).

These tracks, in order of their performance, are a “tai chi warm-up, sun salutations, standing strength, balance, hip openers, core-abdominals, core-back, twists, forward bends-hamstrings, relaxation and meditation” (Les Mills, 2004b). If a participant was unable to attend a scheduled session, they were asked to take part in a replacement at their local leisure centre to enable completion of 36 sessions in total prior to post-intervention testing. The class structure and choreography of the suggested replacement BodyBalance session would have been identical to that being performed for the study.

Table 2. Breakdown of the BodyBalance 25 workout

Track	mins.	Objective	Main composition
1	4.40	Warm up	Tai chi: Centering, breathing, mobility
2	6.20	Sun Salutations	Yoga poses: Mountain, down/up dog, cobra
3	6.30	Standing Strength	Yoga poses: Warrior, triangle
4	4.40	Balance	Yoga poses: Mountain, tree, star, eagle
5	4.30	Hip Openers	Yoga poses: Mountain, swan, half lotus, frog
6	4.40	Core – Abdominals	Yoga, Pilates/Feldenkrais: leg raise, curls
7	4.00	Core – Back	Yoga poses: Horse, crocodile, locust, bow
8	4.35	Twists	Yoga: Mountain pose, balance twists, lunges
9	4.25	Forward Bends	Stretches inc. hamstring, adductor, oblique
10	5.20	Relaxation	
11	2.05	Meditation	

Control Group

Participants in the control intervention group attended a monthly 90-minute lunchtime discussion group formed around aspects of nutrition, health and exercise. These supervised lectures compensated somewhat for the possibility of positive influences upon mood derived from social group stimulation (Desharnais, Jobin, Cote, Levesque and Godin, 1993) and instructor attention without producing a training effect. They were asked to refrain from starting additional exercise regimes or dietary weight loss programmes until after post-intervention testing.

Dietary analysis

The instruction given to participants was to maintain their current diet and exercise regime. In order to determine if any significant changes had occurred in their calorific intake or energy expenditure that would unduly influence the results, participants completed two 3-day diet and exercise record sheets (see appendix xi); these were administered over the same days of the week in the first and last weeks of the intervention period.

Statistical analysis

Data established at both baseline and post-intervention tests were analysed using a mixed model ANOVA on SPSS (version 11.5) software. All data were expressed as mean and standard deviation (*s.d.*). A 2x2 ANOVA determined differences between groups and any resulting group by time interactions. Mean values were calculated from data entered into a table format for each variable within the experimental and control

groups respectively. Post-hoc tests were performed using independent and paired samples t-tests as appropriate. Independent t-tests were used post-hoc to examine any observed differences between the two groups at commencement of the study. Likewise, paired samples t-tests investigated significant differences between the preliminary and post-intervention results within each group. Statistical significance of the main effects was set at $P < 0.05$.

4.4 RESULTS

The BodyBalance group and control group did not differ significantly at baseline for all anthropometric, physiological and psychological measures with two exceptions. These are for pulmonary function, in respect of forced expiratory ratio of FEV₁/FVC, and the GHQ-12 that identified depressive and anxiety-related disorders within the two-week period preceding its completion. Subsequent analysis of these factors found no statistically significant differences in the ensuing change over the 12-week intervention period. There were no significant changes in the control group between baseline and the post-testing session.

Comparisons of anthropometric data are displayed in Table 3. Repeated measures ANOVA indicated only a trend ($F_{(1,32)} = 4.10$; $P = 0.051$) towards a loss in body mass from 71.5 ± 13.4 kg to 70.6 ± 12.1 kg. However, it did display a highly significant effect of BodyBalance intervention on body composition ($F_{(1,32)} = 7.68$; $P < 0.01$) with a reduction in skinfold from $34.0 \pm 5.9\%$ to $32.9 \pm 5.2\%$ ($t = 4.44$, $P < 0.01$). This reduction in body fat was reinforced by the circumference measurements taken in the

region of the trunk. Waist girth reduced significantly ($F_{(1,32)} = 16.58$; $P < 0.01$) from 85.2 ± 10.7 cm to 82.7 ± 9.2 cm ($t = 3.65$, $P < 0.01$) and hip girth ($F_{(1,32)} = 4.80$; $P < 0.05$) from 104.1 ± 8.2 cm to 103.2 ± 7.4 cm ($t = 2.55$, $P < 0.05$). The sum of the six sites for which girth was measured was also highly statistically significant ($F_{(1,32)} = 9.82$; $P < 0.01$), being reduced from an overall total of 412.6 ± 35.3 cm to 408.2 ± 31.2 cm ($t = 3.13$, $P < 0.01$).

Table 3. Anthropometric measures (mean \pm s.d.)

Parameter	Control group (n = 17)		BB group (n = 17)		P Value ^a
	Baseline	Post-Treatment	Baseline	Post-Treatment	
Body mass (kg)	75.0 \pm 17.4	75.3 \pm 16.8	71.5 \pm 13.4	70.6 \pm 12.1	0.051
BMI	26.7 \pm 5.4	26.8 \pm 5.2	26.0 \pm 4.6	25.7 \pm 4.2	0.087
Body fat (%)	31.5 \pm 7.0	31.4 \pm 7.1	34.0 \pm 5.9	32.9 \pm 5.2**	0.009
Arm Girth (cm)	31.3 \pm 4.7	31.4 \pm 4.7	31.3 \pm 3.9	31.1 \pm 3.4	0.131
Chest girth (cm)	97.6 \pm 10.5	97.4 \pm 10.3	94.5 \pm 7.3	94.0 \pm 6.8	0.553
Waist girth (cm)	87.9 \pm 16.1	88.7 \pm 16.3	85.2 \pm 10.7	82.7 \pm 9.2**	<0.001
Hip girth (cm)	105.3 \pm 10.4	105.5 \pm 9.6	104.1 \pm 8.2	103.2 \pm 7.4*	0.036
Thigh girth (cm)	61.0 \pm 7.0	62.5 \pm 9.0	59.7 \pm 5.4	59.9 \pm 5.0	0.248
Calf girth (cm)	38.7 \pm 4.1	38.5 \pm 4.0	37.9 \pm 2.9	37.4 \pm 2.9	0.094
Σ girths (cm)	421.9 \pm 49.0	423.0 \pm 48.4	412.6 \pm 35.3	408.2 \pm 31.2**	0.004

BB, BodyBalance; ^a time*group interaction; BMI, Body mass index; * $P < 0.05$;

** $P < 0.01$.

Table 4. Cardiorespiratory, strength and flexibility measures (mean \pm s.d.)

Parameter	Control group (n = 17)		BB group (n = 17)		P Value ^a
	Baseline	Post Treatment	Baseline	Post Treatment	
Mean IVC (l)	3.3 \pm 0.9	3.2 \pm 0.8	3.2 \pm 1.0	3.4 \pm 0.9	0.192
Mean FVC (l)	3.2 \pm 0.8	3.3 \pm 0.8	3.3 \pm 0.8	3.3 \pm 0.8	0.062
Mean FEV ₁ (l)	2.9 \pm 0.7	2.9 \pm 0.7	2.8 \pm 0.5	2.8 \pm 0.5	0.443
FEV ₁ /FVC (%)	90.4 \pm 7.9	88.2 \pm 10.2	84.8 \pm 6.2	85.1 \pm 4.6	0.220
SBP (mm Hg)	125.4 \pm 21.8	123.1 \pm 21.9	114.4 \pm 13.2	112.8 \pm 11.7	0.894
DBP (mm Hg)	78.4 \pm 11.7	77.3 \pm 14.6	72.0 \pm 9.9	73.6 \pm 8.7	0.439
Resting HR (bpm)	77.9 \pm 15.7	76.2 \pm 14.6	69.6 \pm 6.5	71.4 \pm 9.8	0.293
Exercise HR (bpm)	144.3 \pm 17.5	143.7 \pm 19.1	137.4 \pm 17.6	136.6 \pm 17.5	0.943
Back Strength (kgf)	65.8 \pm 29.7	67.8 \pm 28.4	75.6 \pm 35.9	92.7 \pm 28.1**	0.003
Sit and Reach (cm)	36.5 \pm 8.2	36.1 \pm 9.3	34.2 \pm 6.6	40.1 \pm 5.7**	<0.001
Hip flexion (°)	109.6 \pm 13.3	110.3 \pm 13.4	113.8 \pm 10.6	123.7 \pm 8.2**	<0.001
Hip extension (°)	16.3 \pm 24.9	10.1 \pm 5.6	10.7 \pm 8.1	18.3 \pm 8.5**	0.026
Hip abduction (°)	33.0 \pm 8.5	31.5 \pm 6.9	29.7 \pm 9.5	39.7 \pm 9.3**	<0.001
Lateral flexion (°)	62.3 \pm 7.4	60.5 \pm 10.1	64.1 \pm 9.4	67.1 \pm 8.1*	0.025

BB, BodyBalance; ^a time*group interaction; IVC, inspiratory vital capacity; FVC, forced vital capacity; FEV₁, forced expiratory volume in the first second; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; * $P < 0.05$; ** $P < 0.01$.

No significant changes were displayed in any pulmonary or cardiovascular data (Table 4). This included a measure of aerobic power (exercise HR) as determined by the 3-min step test. However, significant group over time interactions were shown for the back strength and flexibility of muscles surrounding the “core”. Maximal isometric strength of the lower back increased ($F_{(1,32)} = 10.29$; $P < 0.01$) in the BodyBalance group from 75.6 ± 35.9 kgf to 92.7 ± 28.1 kgf ($t = -4.59$, $P < 0.01$). Likewise all five tests related to flexibility also increased. Firstly, the sit-and-reach test ($F_{(1,32)} = 42.97$; $P < 0.01$) changed from 34.2 ± 6.6 to 40.1 ± 5.7 cm ($t = -9.50$, $P < 0.01$). Next the “range of motion” resulting from hip flexion ($F_{(1,32)} = 15.27$; $P < 0.01$), extension ($F_{(1,32)} = 5.43$; $P < 0.05$) and abduction ($F_{(1,32)} = 51.04$; $P < 0.01$) were enhanced from $113.8 \pm 10.6^\circ$ to $123.7 \pm 8.2^\circ$ ($t = -4.82$, $P < 0.01$), $10.7 \pm 8.1^\circ$ to $18.3 \pm 8.5^\circ$ ($t = -7.04$, $P < 0.01$) and $29.7 \pm 9.5^\circ$ to $39.7 \pm 9.3^\circ$ ($t = -8.40$, $P < 0.01$) respectively. Finally, lateral flexion ($F_{(1,32)} = 5.55$; $P < 0.05$) increased from $64.1 \pm 9.4^\circ$ to $67.1 \pm 8.1^\circ$ ($t = -2.21$, $P < 0.05$).

A pilot study conducted in anticipation of the current study evaluated proposed “balance” criteria and calculation formulae. Results showed the methods selected to be adequate for use in the current study. Data from the current “balance” tests were extracted at both preliminary and post-treatment testing sessions and entered into the respective formula. However, the results of the calculations produced an outcome that seemed to be approximately ten times larger than expected. Further investigation isolated additional electrical noise that was responsible for this pollution. Data were deemed invalid and no measures were accepted.

Table 5. Psychological Measures (mean \pm s.d.)

Parameter	Control group (n = 17)		BB group (n = 17)		<i>P</i> Value ^a
	Pre-Treatment	Post-Treatment	Pre-Treatment	Post-Treatment	
STAI –Y2	38.8 \pm 8.6	35.9 \pm 10.1	40.0 \pm 9.6	37.7 \pm 11.1	0.836
GHQ-12	9.4 \pm 4.2	9.0 \pm 3.0	13.9 \pm 7.0	9.2 \pm 6.7	0.059
STAI-Y1	32.2 \pm 7.7 ^b	35.3 \pm 8.8 ^c	29.6 \pm 10.0 ^b	26.9 \pm 7.6 ^c	0.022
STAI-Y1 week 1	33.6 \pm 10.0	32.2 \pm 7.7 ^b	38.8 \pm 14.1	29.6 \pm 10.0**	0.011
STAI-Y1 week 6	31.4 \pm 7.9	31.9 \pm 7.7	32.7 \pm 9.1	26.1 \pm 7.8**	0.001
STAI-Y1 week 12	36.0 \pm 7.6	35.3 \pm 8.8	34.1 \pm 9.8	26.9 \pm 7.6**	0.003
[STAI-Y1 @Wk 1,6 & 12; (pre)- measure start of class, (post) -measure end of class]					
POMS WEEK 1					
Tension	2.0 \pm 3.5	1.1 \pm 2.0	3.4 \pm 3.0	1.3 \pm 2.8	0.131
Depression	1.7 \pm 2.8	0.8 \pm 1.3	3.2 \pm 4.7	1.2 \pm 2.8	0.347
Anger	1.2 \pm 2.8	0.5 \pm 1.1	3.0 \pm 4.4	0.9 \pm 2.5	0.173
Vigour	8.8 \pm 3.2	8.9 \pm 3.4	7.4 \pm 3.0	7.4 \pm 3.6	0.946
Fatigue	3.6 \pm 3.5	3.0 \pm 3.1	4.2 \pm 3.8	4.8 \pm 4.3	0.284
Confusion	2.1 \pm 3.8	1.3 \pm 1.8	3.2 \pm 3.9	1.8 \pm 2.9	0.556
POMS MID-INTERVENTION					
Tension	1.6 \pm 2.9	1.1 \pm 1.5	1.2 \pm 1.3	0.6 \pm 1.3	0.792
Depression	1.1 \pm 2.1	0.9 \pm 1.7	1.1 \pm 1.9	0.4 \pm 1.2	0.263
Anger	0.6 \pm 1.6	0.6 \pm 1.5	1.2 \pm 2.1	0.1 \pm 0.3	0.086
Vigour	8.8 \pm 3.5	8.6 \pm 3.2	7.7 \pm 3.6	7.9 \pm 3.6	0.720

Fatigue	3.5 ± 3.0	4.4 ± 4.7	3.0 ± 2.1	2.4 ± 2.2	0.205
Confusion	1.6 ± 1.8	1.7 ± 2.3	1.4 ± 2.0	0.7 ± 1.5	0.121
POMS WEEK 12					
Tension	1.7 ± 1.4	1.5 ± 2.0	1.9 ± 2.1	0.6 ± 1.2**	0.032
Depression	1.7 ± 2.5	1.1 ± 1.8	1.7 ± 2.2	0.6 ± 1.2	0.226
Anger	1.2 ± 2.2	0.8 ± 1.5	1.1 ± 2.0	0.1 ± 0.3	0.289
Vigour	9.0 ± 3.7	8.9 ± 3.9	8.9 ± 2.8	8.2 ± 3.1	0.535
Fatigue	2.9 ± 3.4	3.1 ± 4.2	3.2 ± 3.5	2.1 ± 1.9	0.098
Confusion	1.7 ± 2.1	1.4 ± 1.9	1.7 ± 2.2	0.9 ± 1.5	0.287
TMD week 1	41.9 ± 14.6	37.8 ± 7.8	49.7 ± 20.2	42.6 ± 15.5	0.509
TMD week 6	39.6 ± 10.9	40.2 ± 10.2	40.2 ± 9.5	36.2 ± 7.0	0.168
TMD week 12	40.2 ± 10.8	38.9 ± 10.6	40.7 ± 12.4	36.1 ± 7.0	0.177

BB, BodyBalance ; ^a time*group interaction; ^b measure taken at end of first class;

^c measure taken at end of final class; STAI, State Trait Anxiety Inventory; GHQ-12, 12-item General Health & Quality of Life; POMS, profile of mood states; TMD, total mood disturbance; * $P < 0.05$, ** $P < 0.01$.

The final area investigated in this study relates to psychological data obtained using specific questionnaires; namely STAI-Y1, STAI-Y2, POMS and GHQ. There were no significant changes in trait-anxiety (STAI-Y2) from baseline in either of the groups. State-anxiety (STAI-Y1), however, was influenced significantly from commencement to

completion of a class. The results, recorded on three occasions, showed a reduction from 38.8 ± 14.1 to 29.6 ± 10.0 ($t = 4.02$, $P < 0.01$) in week 1, 32.7 ± 9.1 to 26.1 ± 7.8 ($t = 4.34$, $P < 0.01$) week 6 and 34.1 ± 9.8 to 26.9 ± 7.6 ($t = 5.38$, $P < 0.01$) in week 12. ANOVA showed significant interactions between groups and across time for each of these three classes ($F_{(1,31)} = 7.35$; $P < 0.05$, $F_{(1,31)} = 12.83$; $P < 0.01$ and $F_{(1,31)} = 10.82$; $P < 0.01$). There was also a significant interaction noted ($F_{(1,31)} = 5.85$; $P < 0.05$) from the end of the first class in week 1 to the end of the last class in week 12. The POMS questionnaires were completed at the same three classes during intervention as the STAI-Y1. The only significant group interaction ($F_{(1,31)} = 5.05$; $P < 0.05$) highlighted for all parameters assessed on the POMS was for “tension” resulting from a class in week 12. General health and quality of life showed a trend towards improvement ($F_{(1,31)} = 3.84$; $P = 0.059$) with a change in the exercise group from 13.9 ± 7.0 to 9.2 ± 6.7 ($t = 2.88$, $P < 0.05$).

4.5 DISCUSSION

With an increasing trend to encourage participation in holistic exercise, there is both the need and opportunity to develop research within this field. The purpose of the current study was to investigate longitudinal changes in a variety of physiological and psychological measures for participants partaking in the “BodyBalance” training programme. These are discussed in light of previous investigations into yoga, tai chi, Pilates and Feldenkrais. It should be noted that, as a necessary part of methodological structure, it was felt essential to monitor both groups to encourage adherence to the programme. Consequently, the authors were aware of participant group affiliation during

the final assessment. The magnitude of differences found in the experimental group in addition to the relatively objective, mechanical measures being made would obviate against the importance of subconscious measurement bias being the cause of the main effect of intervention.

The first physiological measure under consideration is body mass, which altered slightly during the course of the exercise intervention programme. Although this was not significant, it did indicate a trend towards a reduction in weight. It was also not sufficient to influence the Body Mass Index (BMI). The current research did note a significant group reduction ($P < 0.01$) in body fat along with an overall decrease ($P < 0.01$) in the sum of girths measured at six sites. Out of the sites, the two that posed significant changes were the waist and hip measures. These adaptations, considering a non-significant change in weight, would seem to indicate an increase in lean body mass especially around the trunk region. Earlier investigations recording mass, BMI and body composition parameters highlighted the absence of change, possibly due to frequency of sessions, duration of intervention or the modality of Pilates (Jago *et al.*, 2005; Segal *et al.*, 2004).

A number of earlier studies using yoga intervention, that measured vital capacity along with inspiratory and expiratory pressures, resulted in significant improvements in pulmonary measures (Birkel *et al.*, 2000; Madanmohan *et al.*, 1992). This is unlike the findings of the current study where no significant changes were determined within such factors. In addition, there were no changes to SBP and DBP readings. Although a study

conducted with tai chi over a 12-month period (Thomas *et al.*, 2005) supports these findings, other research based around yoga breathing and yoga exercise treatment (Murugesan *et al.*, 2000; Sung *et al.*, 2000) produced a significant reduction in BP. The reason for this may be the proportion of breathing exercises and relaxation incorporated within the yoga workouts as opposed to that within BodyBalance or the form of tai chi undertaken. With respect to the components of fitness, the ACSM guidelines for flexibility (1995; p170) recommended participants should attempt to exercise “at least 3 days per week [with a] major emphasis on [the] lower back and thigh area”. They suggest that the lack of flexibility in specified areas may have connections to CLBP. BodyBalance, performed on three separate occasions during each week of the intervention period, fulfils this criterion. The study also supports the programme’s effectiveness to increase flexibility as tests for sit-and-reach, hip flexion, hip extension, hip abduction and lateral flexion all displayed significant improvements. However, an increase in flexibility is not always the outcome of holistic-style exercise (Song *et al.*, 2003). Another component of fitness is strength and of particular interest to this study, concerned with “core” type training methods, is back strength. The back strength dynamometer, which measures maximal force generated by the extension of the lower back in 1- repetition maximum (1-RM), indicated a significant improvement in the strength of that muscle group. This reinforces the improvement in trunk strength additionally supported by abdominal strength gains ($P < 0.01$) found by Song *et al.* (2003) in a tai chi study. No changes, however, were discovered in aerobic power although improvements were found in a tai chi study that utilised the same 3-minute step test as a measure (Hong *et al.*, 2000). One contributory factor to the outcome may have

been the age group, as the tai chi participants were older adults whereas the BodyBalance group had an average age of 44 years.

The results from the balance tests for this study contained errors due to noise pollution. However, they did create interest for the investigator as they indicated a possible effect upon balance. Previous tai chi studies had also found an influence upon balance, especially for the elderly population (Hong *et al.*, 2000; Xu *et al.*, 2004), although not in all cases (Wolf *et al.*, 1996). It would be of benefit to assess the balance element of BodyBalance in future research.

The last area under scrutiny covers psychological parameters and relates predominantly to state-anxiety as defined by the STAI-Y1 and trait-anxiety as defined by the STAI-Y2. The STAI-Y1 questionnaire is used to assess how participants feel at a particular moment in time. The outcome of the 20-item questionnaire, completed before and after three specified classes, showed a significant reduction in anxiety following 60-minutes of BodyBalance. This is in agreement with Berger & Owen (1992) who reported that hatha yoga produced significant short-term reductions in state-anxiety following exercise and Kerr *et al.* (2002) who showed state-anxiety scores to decrease significantly over a single lesson of Feldenkrais. A comparison of state-anxiety from the end of the first class to the end of the last class, however, showed a decrease in the experimental group in contrast to an increase in the control group. This fall in anxiety of the experimental group was not sufficient in itself to show statistical significance. This is in accord with no significant differences found in trait-anxiety recorded using the STAI-Y2

over the course of the intervention period. However, these longitudinal findings undermine Kerr *et al.* (2002) who found state-anxiety measured using the 20-item STAI improved significantly from baseline to the end of the 10-week intervention period. Possible reasons for the differences encountered may be the “new student” and “returning student” division with no indication of a control group by Kerr *et al.*, and that Feldenkrais is often regarded as a more sedentary exercise session when compared with BodyBalance. Finally, the results of the POMS in this study do not support Kolt *et al.* (2000) who assessed Feldenkrais participants for state-anxiety on four occasions over two-weeks using the 12-item POMS-B1 questionnaire, ultimately reporting significantly lower scores. Kolt suggested the results may have been due to participants anticipating a change in anxiety. Following the large number of tests completed and the longer intervention period for the current study, this effect would be negligible, leaving results to show significance only in the tension component at week 12. In turn, it is possible that this could be attributed to participant concerns that it was the final session.

4.6 CONCLUSION

In conclusion, the findings of the current study reinforce the concept behind BodyBalance exercise as a means of strengthening the core or central region of the body. Along with changes in flexibility, this mind-body programme could strengthen body tone and possibly lead to a reduction in associated ailments and conditions such as chronic back pain. This, in conjunction with the reduction in state-anxiety, would support some of the claims presented by the company behind BodyBalance. There were, however, many cardiorespiratory and mood states that were not influenced even though changes

had been apparent in literature underlying the holistic disciplines from which BodyBalance has been derived. Additional research is suggested to investigate parameters such as balance and posture that may arise following changes in core strength and flexibility.

Chapter 5

**Investigating Measures of Postural Control and
Trunk Endurance as Indicators of Chronic Low
Back Pain**

2007

School of Human and Life Sciences
Roehampton University

Study 2 – Balance control and the “Core”

“Fitness may be defined as the degree of adaptation to the stressors of a given lifestyle”

Dick, F., 1978

5.1 INTRODUCTION

The principal objective of the thesis, as stated at the outset, was the exploration of mind-body exercise formats designed to enhance core strength and endurance.

Furthermore, this investigation directed itself towards the impact of those formats on back pain. A comprehensive literature review around the areas of holistic exercise programmes, along with CS and the back, provided the contents of chapters two and three. Chapter four, the first of three studies designed to address the question proposed by the thesis, followed this using a conventional scientific structure. It set the scene by utilising a widely available mind-body programme, on thirty-four healthy volunteers over a twelve-week period, to determine changes of a physiological and psychological nature.

The literature review in chapter four allowed study one to expand upon preceding chapters by discussing claims made by the specific exercise programme as to their health-related benefits. The second study of the series, now the basis for chapter five, will require formatting in a slightly different manner. The literature review for this study will be somewhat brief and build further upon the available research into postural control, back strength and endurance. However, a pilot study will need to be conducted using the *RSscan* and Kistler, to establish which would prove to be the most appropriate equipment for the balance tests proposed. An additional reason also lies in the fact that, to date, no current published balance study has utilised the *RSscan* with humans. A literature review

included within the pilot study will enhance the total literature reviewed in study two by providing more in-depth information on both pieces of equipment in relation to posture and balance. Once the exploratory study is complete, the remainder of the chapter, from methodology of study two onwards, can be continued in the usual manner.

The structure of the thesis to date has been explained above but consideration also needs to be given to the aims of the studies thus far and why they have been amended in part. The first study undertaken for this research project (Khan, Marlow & Head; 2007) established that adaptations arising from BodyBalance produced a beneficial effect upon the “core” region of the body. The aim originally suggested for the second study revolved around comparisons of posture, balance, core-strength and flexibility between three distinct groups of long-term mind-body exercise practitioners. The sub-groups of exercisers indicated consisted of those regularly participating in Pilates, yoga or BodyBalance alongside a non-exercising control group. The idea was to investigate specific associations between exercisers and the benefits derived from their form of discipline. However, a more pertinent question arising from the findings of the first study was whether a basic difference existed in core-strength or endurance between participants with and without back pain. Consequently, the objective of the thesis remains unchanged but the current study has focused more appropriately towards exploring the link between back pain sufferers and various trunk measures. The expectation is that this research will be of greater benefit as it focuses more on the aim of the thesis, in addition to supplying missing information between the initial and concluding studies. Aspects of trunk measurements needing evaluation suggest that the

parameter of trunk endurance, rather than trunk strength, would prove a more appropriate measure. This is because endurance has recently been shown to be an effective indicator of first-time low-back injury (Udermann, Mayer, Graves and Murray; 2003). To promote greater control and accuracy of external factors both the pilot and main study will be laboratory-based.

The research question underlying study two concerns itself with “assessment of balance and trunk strength in participants with and without chronic back pain” by comparing postural control and endurance. The experimental hypothesis anticipates that back pain sufferers will display lower trunk endurance and balance control than the non-back pain control group. Should the results suggest that those participants free from back pain attain superior core measures, the design of the final study will look towards applying BodyBalance intervention upon chronic back pain sufferers to assess its effects upon symptoms. The outcome of this study will be influential in supporting future use of mind-body exercise as an alternative means of preventing and treating chronic back pain.

5.2 LITERATURE REVIEW

The overall purpose of this second study, within the realms of exercise and back pain, is to determine whether there are differences in selected parameters between those who live with the burden of CLBP and those who do not. The parameters referred to in this instance relate primarily to physiological and biomechanical aspects associated with the “core”, and the ease and ability with which an individual can maintain a pain-free existence in everyday life. A good basis upon which to accomplish this would be to

look at research conducted in the area of postural control followed by strength and endurance of the trunk. There would also need to be some insight into the extent of pain experienced by the individual and the perceived impact on their daily routines.

Postural control can be assessed in numerous ways but a commonly used method is the calculation of “postural sway” (Gerbino Griffin & Zurakowski, 2007; Schumann *et al.*, 1995). This measure was amongst the balance tests selected for study one of this thesis but the extracted data was later discarded as it incorporated elements of noise pollution that raised recorded levels of sway almost tenfold. To gain a more accurate picture of postural control through balance measures, it would therefore be necessary to either amend the earlier methodology or establish an alternative test to incorporate within the design of this study.

Postural control tests are generally categorised either as static or dynamic. Static assessment can be evaluated using stance time or a force plate in various Romberg test configurations (Gerbino *et al.*, 2007; Onambele, Narici, Rejc & Maganaris, 2007). Under a variety of such upright standing conditions, Mientjes *et al.* (1999) investigated the balance responses of eight CLBP participants and eight healthy controls. Their force plate measurements were correlated with the Oswestry and Roland Disability questionnaires that evaluated the severity of the disability. The study concluded that the root mean square calculated was a reliable and sensitive enough measure, particularly in the medial-lateral plane, to detect a significant increase in the postural sway of the back pain group. Likewise, a study on balance by Byl and Sinnott (1991) found a

significantly greater postural sway in twenty low-back pain participants when compared with twenty-five healthy back participants. Concerning the variations in the Romberg test conditions often used, Hoffman, Schrader, Applegate & Koceja (1998) showed that there was no difference between the dominant and non-dominant leg in the single-leg stance of a young adult population. Dynamic assessment, on the other hand, is often evaluated either using time in balance on a stabilometer or seesaw, by tests such as “get up and go” or through dynamic posturography. The latter has been used in studies relating to back pain such as Volpe, Popa, Ginanneschi, Spidalieri, Mazzocchio & Rossi (2006) which, like Mientjes *et al.* and Byl *et al.* above, displayed an increased sway in CLBP participants, although this time in the anterior-posterior direction. When considering static and dynamic balance, caution should be advised when trying to establish a relationship between the tests. Hrysomallis Laughlin & Goodman (2006), investigating the direct relationship between the two states of balance in footballers, concluded that the static balance tests were not reflective of dynamic and inferring dynamic balance from static should be avoided.

The second area requiring consideration revolves around core-strength and endurance of the trunk area. Abdominal and back muscle endurance tests are often underrated due to their inclusion of additional muscle groups such as the hip flexors (Demoulin *et al.*, 2004; ACSM, 1973; p82; Moreau, Green, Johnson and Moreau, 2001). The core area under scrutiny in this study, however, involves the working of the trunk as a “whole”, so the sit-up and back-extension tests would be considered a valid method of measurement. Furthermore, it has been shown that patients with low-back pain have

significantly shorter endurance times for lumbar extensors, supporting once again the suggestion that endurance should be deemed an indicator of first time low-back injury (Udermann *et al.*, 2003). This would therefore reinforce the decision to incorporate such endurance tests as an appropriate measure in the test battery.

A number of tests have been developed and are available to assess back extensors but these need to be evaluated for their impact upon participant safety. The test ultimately selected would therefore need to be suitable for both healthy and clinical populations (Pitcher, Behm and MacKinnon, 2007, p549). The Biering-Sørensen test (Biering-Sørensen, 1984; McGill, 2007, p211) has been used on many occasions under these circumstances because it does not require maximal effort, which is often difficult to produce in the presence of acute pain. Consequently, it would also reduce the risk of instigating a recurrence of back pain due to performance of the test itself. Designed to measure fatigue times, the Sørensen test has been regarded as the most frequently reported test in “Isometric Back Endurance” literature and a valid measure for back muscle fatigue (Moreau *et al.*, 2001; p111; Coorevits, Danneels, Cambler, Ramon and Vanderstraeten, 2008). A study by Latimer, Maher, Refshauge and Colaco (1999), questioned the reliability of the Biering-Sørensen procedure. Looking at sixty-three participants, it found that those asymptomatic for low-back pain had significantly longer holding-times than those displaying symptoms. It concluded that the test was able to discriminate between participants with and without low-back pain. This is in keeping with the results established by Tekin, Ortancil, Ankarali, Basaran, Sarikaya and Ozdolap (2009), who tested one hundred and fifty Turkish coal miners and determined a greater

hold-time for those without back pain. Mannion (2001) showed endurance time from Biering-Sørensen increased significantly in chronic back pain participants following active physiotherapy, muscle reconditioning and low-impact aerobics. Likewise, Moffield *et al.* (1993) found an exercise group that trained twice daily for 6-weeks with a given protocol increased their isometric hold-time significantly by 22%. The same study also suggested some uncertainty surrounding the use of this test because, due to the manner in which it provides a collective measure of trunk endurance, it does not take into account the portion contributed by the other possible muscles such as the gluteus or hamstring.

Included within the category of Sørensen are those tests with minor variations classified as “modified Sørensen tests”. These variants could be changes such as hands placed on the head, arms extended by the sides of the body rather than folded under the chest, fewer stabilising straps or different methods of assessing at what point the horizontal position has been compromised (Moffroid, Haugh, Haig, Henry and Pope, 1993; Moreau *et al.*, 2001).

The final topic requiring some deliberation would be the perception of pain experienced by an individual around the time of testing. A number of questionnaires currently exist to determine the level of disability in CLBP participants including the Roland-Morris Disability Questionnaire ((RMDQ) Roland and Morris, 1983) the Oswestry Low-Back Pain Disability Questionnaire ((OLBDQ) Fairbanks, Couper, Davies and O’Brien, 1980) and the Quebec Back Pain Disability Scale ((QDS) Kopec,

Esdaile, Abrahamowicz, Abenhaim, Wood-Dauphinee, Lamping and Williams, 1995). All these outcome measures show both satisfactory levels of test-retest reliability as well as a correlation between them and are deemed appropriate to evaluate either acute or chronic pain participants (Enebo, 1998; Davidson and Keating, 2002). The latter of the three more specifically targets those with CLBP. It indicates perceived difficulty associated with the completion of simple tasks and takes approximately five minutes to complete.

5.3 PILOT STUDY: Force Platform or Pressure mat?

5.3.1 PILOT STUDY - INTRODUCTION

Measurement reliability refers to the extent “results obtained by a measurement procedure can be replicated” (Emery, 2003; p496). In order to use balance assessment as an outcome measure of postural control, particularly in connection with the influence of back pain, the reliability of the selected test is of the utmost importance. One of the most commonly used instruments for balance assessment in studies has been the force platform or force plate (Verhagen, Bobbert, Inklaar, Kalken, Beek, Bouter and Mechelen, 2005; Wolff *et al.*, 1998; Koceja *et al.*, 1999). This consists of a rigid plate supported by a force transducer in each of the four corners that records the three components of applied force and their respective moments (Hasan *et al.*, 1990; Slobounov *et al.*, 1996). The shift in the position of the vertical component is used to evaluate movement of the COP and, consequently, balance. The force platform’s greatest advantage over other instruments used to determine balance would be the availability of previous research, particularly in terms of validity.

An alternative, more recent assessment method that could be used for balance testing is the pressure distribution plate or force platform. This comprises a three-dimensional plate with a number of conductive pressure-sensitive sensors that measure vertical force alone. The size of each sensor is predetermined, which therefore allows pressure to be calculated. It should be noted, that although the force platform has only four sensors, these still produce a number of points that could make it somewhat comparable with the numerous sensor readings of the pressure plate. The calibration of the pressure plate is conducted either with a participant of known body weight so that the accuracy of data would also be reliant upon this parameter or, in order to obtain greater accuracy, in conjunction with the force platform. In the latter instance, every frame recorded by the pressure plate is recalibrated with the corresponding frame from the force plate.

One solution to determine which of the two methods would prove the most appropriate for balance testing in this second study was to test both pieces of equipment independently to see which would prove the more reliable. Furthermore, a number of additional factors would also need to be taken into considered alongside the outcome of these tests. These include the relative effect of noise or drift in the force plate recording, the accuracy level of the newly developed footscan pressure mat and the benefit of placing the pressure mat on the force plate in order to calibrate using the force plate. The hypothesis is that the pressure plate would be the most accurate in terms of reliability due to the influence of noise on the force platforms. Should this be the outcome, the footscan would therefore be used in study two.

5.3.2 PILOT STUDY - LITERATURE REVIEW

A large percentage of studies that investigate balance often do so in connection with posture, disease or other characteristics such as aging (Wolff *et al.*, 1998; Hoffman, 1998; Hasan *et al.*, 1990; Onambele *et al.*, 2007) that ultimately influence an individual's ability to maintain an upright stance. One method of quantifying and recording this element of balance in humans is by the use of a force platform. The force platform itself has been described as a "...precision instrument" with the Kistler force platform in particular having "... high accuracy and reliability...considered as the reference force plate... [that] never has to be recalibrated" (Mitzoguchi & Calame, 1995; p268). However, this may be more applicable to studies concerned with gait rather than the greater sensitivity needed to determine balance, especially in the "quiet" stance (Ball, 1999; p6). Measurements resulting from the movement of an individual's COP, derived via the x and y co-ordinates of the platform over a specified sample period, can be used to calculate measures of sway such as path length and average velocity that represent the distance travelled or the distance travelled per second over time. Gerbino *et al.* (2007; p505) have suggested that these COP measurements represent "reproducible measures of standing balance". However, a wide range of test protocols have been applied to this area of balance research, for example, single to two-footed stance, eyes-open or eyes-closed and perturbation (Jonsson *et al.*, 2004; Carroll *et al.*, 1993) and this variation would need to be taken into account if research is to be justly compared. The subsequent differences in data collected are also highlighted by Verhagen *et al.* (2006; p1099) who suggested comparison of their particular investigation with other similar studies was made difficult "...due to the various COP

excursion assessment methods used". In addition, they discussed the impact that "other studies" may have had as a consequence of involving participants with functional ankle instabilities whose "impaired proprioception" could have distorted findings, as well as the possible influence on findings caused by the absence of a control group.

Furthermore, Verhagen *et al.* suggested that the fact there were no significant differences found in their study may have been associated either with a learning effect caused by repetitive measurements or by a small sample size that would therefore reduce the statistical power of the study. Another important consideration when using the force plate for balance measurement are the errors that exist in the equipment itself that could consequentially affect body sway measures. Ball (1999; p2) identified three such categories as "equipment error, noise and quantisation error" where equipment included plate distortion and transducer cross talk, noise was both internal and external such as an amplifier and quantisation referred to the difference between an analogue signal and its binary representation. Browne & O'Hare (2000) further suggested a series of "quality control" tests that would help to improve the accuracy of results. One of these was to determine "noise" by applying a calibrated static load to the platform and calculating "...displacement of the COP..." (p520) as a representation of that noise, which should be within 1mm. This method of evaluating the level of noise can then help compensate for any drift that occurs during testing. Carroll *et al.* (1993) is one study that used such a correction formula to adjust the results for electronic drift by multiplying data with a force platform calibration matrix obtained by placing a 50lb weight in the centre of the platform and at each corner. Finally, Middleton, Sinclair & Patton (1999) found the error when calculating COP to be much greater with force

applied to a single point rather than weight distributed between two points. They suggested higher levels of accuracy when the single COP point lay along the midline of the platform, as data deteriorated the further the point moved out towards the edge, and in favour of the x co-ordinate as opposed to the y co-ordinate. There was also some discussion concerning errors as large as ± 20 mm and even ± 30 mm that had been found in related literature when force had been applied at a single point (Middleton *et al.*, 1999; Schmiedmayer & Kastner, 1999).

The footscan system by RSscan (RSscan International, Belgium) uses either pressure sensitive insoles placed inside a participant's footwear or a pressure mat to track changes in COP. The software provided by the company then provides the researcher with the facility to quantify human gait and balance. Only recently has a study been published (Renneboog, Musch, Vandemergel, Manto & Decaux; 2006; p71) that utilises a gait test on the footscan to measure the "total travelled way" of three steps taken "in tandem" by mild asymptomatic hyponatremia patients and a matched control group. This study, however, does not mention reliability of the equipment or explain the calculation of "total travelled way", a figure that is given in the data output provided by the above software. Nonetheless, it is the only study with human participants. Two further studies that have used the footscan pressure plate are by authors Van der Tol, Metz, Noordhuizen-Stassen, Back, Braam and Weijjs (2003) and Rogers & Back (2003) who have evaluated the pressure distribution in the bovine claw and equine hoof, in other words, assessed the gait of dairy cows and horses. Van der Tol *et al.* used a pressure plate assembled on a Kistler force platform that allowed data to be sampled

simultaneously at 250 Hz for 4-seconds. Calibration of the footscan used the force platform allowing the sum of the vertical ground reaction force (GRF) registered on the pressure mat to be automatically adjusted to the total force registered on the Kistler. This study acknowledges the combined use of pressure mat and force plate as a new technique but gives no reference to the reliability of the data. Rogers *et al.* (2003; p306) go further and justify the use of the pressure plate in comparison to the force plate because the data has been "...derived from hundreds of receptor cells..." rather than just four. Their study, calibrating the pressure mat using a known mass of 68kg, suggests footscan "pressure plate ...repeatability of 98% and an accuracy error of 3.3%" (p307). It is not clear how these figures were derived and a later reference to the same high level of repeatability for the "placement of markers on the selected areas of interest" (p308) leaves room for misunderstanding.

5.3.3 PILOT STUDY - METHOD

Experimental Procedure

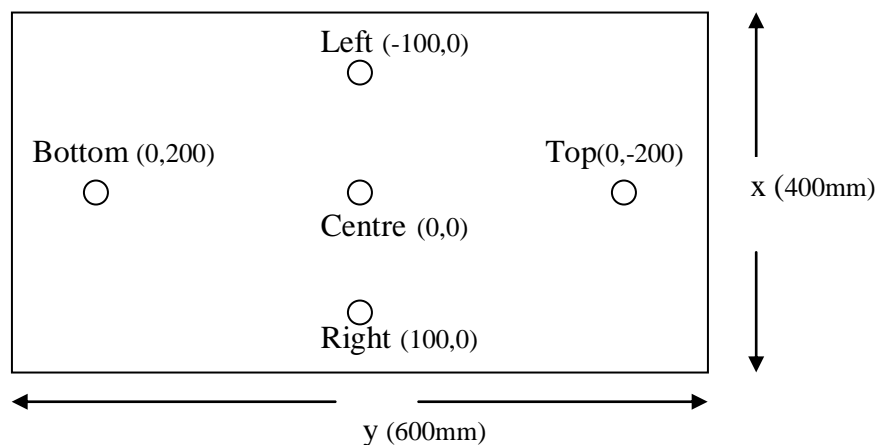
This pilot study took place in the Biomechanics laboratory at the Whitelands campus of Roehampton University in London. Prior to undertaking tests for the pilot study, a preliminary exploration of the two-footed, eyes-open stance using a two-way BNC signal splitter was conducted. The idea of this was to enable simultaneous force platform and pressure plate recordings over a 20-second period to determine whether they gave comparable readings. However, the data from this displayed a path length on the Kistler three times greater than the footscan pressure plate so this option was discarded. At the first testing session for the pilot study, "Test 1" (see overleaf) was

conducted three times in succession for both the force plate and the pressure mat to establish which would be more reliable in determining force and co-ordinates. To assess inter-session reliability for the same two parameters, this test was repeated in the identical order a week later. Finally, in week 3, the “Test 2” battery (see overleaf) was used to investigate intra-session reliability of both pieces of equipment following a “shift” in mass during the trial.

Measurements

Kistler Force Plate

In order to reduce interference, the 600mm x 400mm force plate (Kistler, Type 9281CA) consisting of a top plate with four 3-component sensors, rested on a Kistler 8-plate mounting frame positioned in the floor of the laboratory. The sensors, quartz piezoelectrical transducers located in each of the four corners of the platform, allowed detection of the analogue signals that were amplified by a built-in 8-channel Kistler 9865 amplifier. These were then interfaced, via an analogue to digital converter (ADC), to a “Tiny” computer. Data were filtered for high frequency noise using a low-pass Butterworth filter with a cut-off frequency of 10Hz. The resulting output facilitated force and force-moments acquisition on the medial-lateral, anterior-posterior and vertical axes that allowed for software calculation of the COP position. Calculations were determined using BIOWARE (Type 2812) version 3.2.6.104, a “Windows” software designed for use with Kistler force plates. The amplifier ranges were set at 264N for the sheer and 531N for the vertical range (range 2).

Test 1***Diagram 1.***

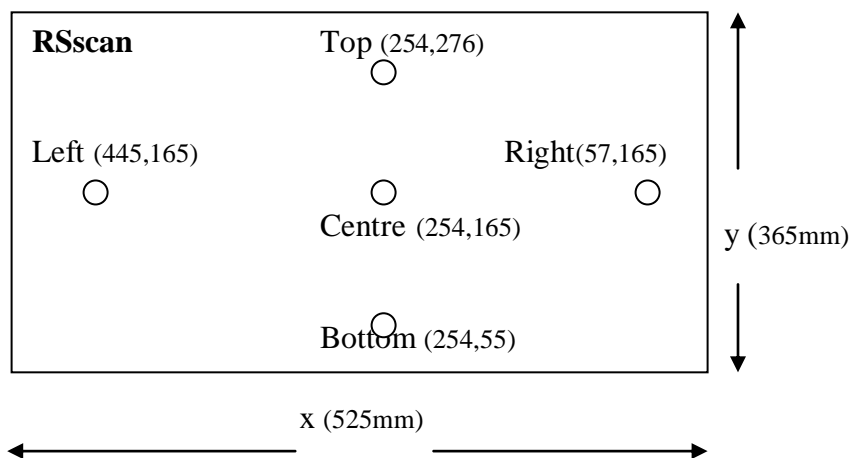
This test was designed to establish the validity of both force and x, y co-ordinates at given points on the Kistler force platform. Five adhesive 3 mm radius markers were placed on its surface as shown in *diagram 1*. First, the platform was tested for accuracy of force. This was determined by placing a 2 kg hand weight (19.62N) in a pre-selected order at each of the five points indicated by the markers and the mass recorded. This process was repeated on two further occasions, again in the same order, following which the mean mass of the three trials at each point was calculated. Next, to allow the accuracy of co-ordinates to be assessed, a pointed stick was placed on each marker for 20 seconds at a sampling frequency of 50Hz and the position of the point of contact recorded. This process was triggered by pressing a key. As above, the test was performed in rotation three times for the centre, top, bottom, left and right dots and the mean used for comparison.

Test 2

This test aimed to investigate the validity of data recorded following a shift in mass of an object on the force platform. In order to simulate a 50 kg person (490.33N) standing on the force plate in a single foot stance, 10 x 5 kg plates were stacked in the centre of the Kistler surface area. Data was sampled at 50Hz for 20 seconds, recording triggered by pressing a key and the resulting mass noted. This process was then repeated on four more occasions. However, during each of these subsequent repetitions an additional 2 kg dumbbell was placed, after approximately five seconds, at one of the four sides of the 50 kg to simulate a shift in the COP. These five trials, 50 kg in the centre for the first then 50 kg increasing to 52 kg (509.95N) with a shift to the top, bottom, left and right for the second, third, fourth and fifth trial respectively, were repeated two more times in rotation.

RSscan Pressure Plate

A 0.5m RSscan pressure plate (RSscan International, Belgium) had a measuring surface area of 525mm x 365mm that encompassed 4096 sensors. This was connected, via an interface box, to an IBM Thinkvision computer operating on Windows 2000. Calibration of the pressure plate was performed using an individual with a known mass. The pressure plate has a repeatability of 98% and an accuracy error of 3.3% (Rogers *et al.* 2003).

Test 1*Diagram 2.*

These tests were designed with the same objective and methodology as test 1 above, but on this occasion to determine validity of force and co-ordinates of the footscan pressure plate. Firstly, the *RSscan* pressure plate was calibrated using an individual with known mass 61 kg and UK shoe size 6. Then, five adhesive markers, radius 3mm, were placed as shown in *diagram 2*. A 2 kg weight was again placed at each of the five markers in turn and recording triggered by pressing a key. For each measurement a total of 998 data points were collected over 20 seconds. Two further trials were conducted at each marker point and the calculated mean of three trials per marker used for analyses. Finally, a pointed stick was placed at each marker for 20 seconds, three times in rotation, with resulting co-ordinates averaged for comparison.

Test 2

In order to investigate the shift in mass on the footscan the same protocol was adopted as per the Test 2 on the Kistler force platform. The pressure plate was calibrated using a person with mass 61 kg and UK shoe size 6. 50 kg of weights were then stacked in the centre of the pressure plate, and used to record data signifying a person holding a static “quiet” one-footed stance. Data was sampled for 20 seconds following which an extra four further tests were to be conducted with an additional 2 kg plate placed above, below, to the left and to the right of the 50 kg plate respectively. Again, this was repeated on two more occasions and the data from the three trials used in analyses.

Statistical analyses

All data derived from the tests of each respective week were expressed as mean \pm standard deviation (*s.d.*) and entered into tables according to the type of equipment; namely Kistler or RSscan. The test 1 results were then further subdivided into those tables displaying results for force readings that used a 2 kg weighted-plate, and those for co-ordinate positions that involved pointed-stick placement. Results were given at each of the five-marker point for both weeks 1 and 2. Intra class correlations coefficients (ICC) were performed to determine the reliability of the force platform and pressure plate measures taken. The Coefficient of Variation (CV%) was calculated to indicate the level of variability in the distribution. The subdivisions for test two were for three successive trials of the 50 kg plate in the centre followed by the four directional shifts involving an additional 2 kg plate. Further pointed-stick tests were also conducted to reinforce intra-session reliability. Again, the CV% was calculated.

5.3.4 PILOT STUDY - RESULTS

Test 1

Table 6. Kistler; Mass 19.61N (mean \pm s.d.)

A 2 kg mass was placed at the 5 marked points on the force platform

	Centre	Top	Bottom	Left	Right
Week 1 (N)	20.19 \pm 0.60	20.33 \pm 0.58	20.25 \pm 0.62	20.20 \pm 0.60	20.39 \pm 0.57
CV%	2.97	2.87	3.06	2.97	2.80
Week 2 (N)	19.85 \pm 0.59	20.20 \pm 0.63	20.06 \pm 0.60	20.29 \pm 0.62	20.19 \pm 0.60
CV%	2.97	3.12	2.99	3.06	2.97

Table 7. RSscan pressure plate; Mass 19.61N (mean \pm s.d.)

A 2 kg mass was placed at the 5 marked points on the footscan

	Centre	Top	Bottom	Left	Right
Week 1 (N)	9.26 \pm 0.32	22.41 \pm 0.60	20.06 \pm 0.76	31.54 \pm 0.77	27.32 \pm 0.60
CV%	3.46	2.68	3.79	2.44	2.20
Week 2 (N)	15.29 \pm 0.96	27.11 \pm 1.24	27.56 \pm 0.89	44.01 \pm 1.34	35.99 \pm 0.60
CV%	6.27	4.57	3.23	3.04	1.67

Test-retest correlation coefficients for both the Kistler and RSscan ranged from $r = 0.81$ to $r = 0.99$ thereby demonstrating high reliability.

Table 8. Kistler; Co-ordinates (mm) (mean \pm s.d.)

A pointed stick was placed at each of the 5 marked points on the force platform

	Centre (0,0)	Top (0,-200)	Bottom (0,200)	Left (-100,0)	Right (100,0)
x: week 1	-1.20 \pm 1.80	-9.10 \pm 1.90	1.30 \pm 1.70	-93.10 \pm 2.40	82.00 \pm 2.60
CV%	150.00	20.88	130.77	2.57	3.17
x: week 2	-3.80 \pm 2.40	-5.30 \pm 2.40	-12.30 \pm 2.20	-104.80 \pm 3.40	88.50 \pm 2.90
CV%	63.16	45.28	17.89	3.24	3.27
y: week 1	5.30 \pm 3.00	-185.90 \pm 4.00	198.20 \pm 4.10	5.30 \pm 3.10	3.10 \pm 3.30
CV%	56.60	2.15	2.07	58.49	106.45
y: week 2	5.50 \pm 3.90	-188.00 \pm 5.60	200.50 \pm 5.00	7.20 \pm 4.30	4.00 \pm 3.90
CV%	70.09	2.97	2.49	59.72	97.5

Table 9. RSscan pressure plate; Co-ordinates (mm) (mean \pm s.d.)

A pointed stick was placed at each of the 5 marked points on the footscan

	Centre (254,165)	Top (254,276)	Bottom (254,55)	Left (445,165)	Right (57,165)
C of x:week1	254.49 \pm 0.04	253.52 \pm 0.02	253.28 \pm 0.02	445.38 \pm 0.02	57.43 \pm 0.04
CV%	0.02	0.01	0.01	0.00	0.07
C of x:week2	253.12 \pm 0.02	253.50 \pm 0.00	253.38 \pm 0.01	445.40 \pm 0.00	57.76 \pm 0.03
CV%	0.01	0.00	0.00	0.00	0.05
C of y:week1	165.04 \pm 0.02	276.42 \pm 0.02	55.24 \pm 0.02	165.89 \pm 0.04	164.09 \pm 0.03
CV%	0.01	0.01	0.04	0.02	0.02
C of y:week2	164.54 \pm 0.04	276.51 \pm 0.03	55.35 \pm 0.03	165.88 \pm 0.03	164.07 \pm 0.04
CV%	0.02	0.01	0.05	0.02	0.02

Test 2***Table 10. Kistler; Mass 490.33N(50 kg) or 509.94N(52 kg) (mean \pm s.d.)***

A 50 kg mass was placed at the centre. An additional 2 kg plate was added to the bottom, left, right & top to signify a shift change on the force platform

	Centre 50kg	Centre 50kg Bottom 2kg	Centre 50kg Left 2kg	Centre 50kg Right 2kg	Centre 50kg Top 2kg
Trial 1 (N)	496.05 \pm 0.65	514.04 \pm 8.11	513.43 \pm 9.07	513.28 \pm 8.69	513.90 \pm 9.16
CV%	0.13	1.58	1.77	1.69	1.78
Trial 2 (N)	497.88 \pm 0.64	512.36 \pm 9.18	512.99 \pm 9.14	512.86 \pm 8.01	513.64 \pm 8.98
CV%	0.13	1.79	1.78	1.56	1.75
Trial 3 (N)	498.03 \pm 0.59	512.25 \pm 9.11	511.64 \pm 10.01	512.23 \pm 8.99	511.56 \pm 9.54
CV%	0.12	1.77	1.96	1.76	1.86

Table 11. RSscan pressure plate; Mass 490.33N(50 kg) (mean \pm s.d.)

A 50 kg mass was placed at the centre.

	Trial 1	Trial 2	Trial 3
Centre (N)*	838.01 \pm 6.35	785.54 \pm 6.29	846.97 \pm 1.53
CV%	0.76	0.8	0.18

**The footscan did not provide any meaningful data when additional weight was added, so the shift data (from bottom, left, right & top) has been omitted.*

Table 12. Kistler; Co-ordinates (mm) (mean \pm s.d.)

A pointed stick was placed at each of the 5 marked points on the force platform

	Centre (0,0)	Bottom (0,-200)	Left (0,200)	Right (-100,0)	Top (100,0)
x: trial 1	-16.50 \pm 0.20	-12.00 \pm 0.30	-22.70 \pm 2.20	-13.60 \pm 2.30	-14.70 \pm 0.80
CV%	1.21	2.50	9.69	16.90	5.44
x: trial 2	-17.90 \pm 0.20	-4.00 \pm 0.30	-19.90 \pm 2.30	-2.40 \pm 3.00	-15.80 \pm 0.90
CV%	1.11	7.50	11.56	125.00	5.70
x: trial 3	-16.30 \pm 0.10	-8.00 \pm 0.20	-13.60 \pm 2.50	-0.90 \pm 2.20	-10.40 \pm 0.40
CV%	0.61	2.50	18.38	244.44	3.85
y: trial 1	4.60 \pm 0.30	3.70 \pm 3.20	-5.90 \pm 1.00	1.00 \pm 0.30	-10.40 \pm 3.20
CV%	6.52	86.49	16.94	30.00	30.77
y: trial 2	-2.70 \pm 0.30	3.20 \pm 3.60	0.90 \pm 0.30	2.30 \pm 3.30	-5.70 \pm 3.30
CV%	11.11	112.5	33.33	143.48	57.89
y: trial 3	-2.20 \pm 0.20	-0.30 \pm 3.60	1.80 \pm 1.20	-3.30 \pm 0.40	-8.30 \pm 3.60
CV%	9.09	1200.00	66.67	12.12	43.37

Table 13. RSscan pressure plate; Co-ordinates (mm) (mean \pm s.d.)

A pointed stick was placed at the centre marker. Other points were not tested for trial 2

	Trial 1	Trial	Trial 3
C of x: week 3	261.51 \pm 0.06	256.66 \pm 0.06	256.35 \pm 0.05
CV%	0.02	0.02	0.2
C of y: week 3	162.84 \pm 0.06	164.07 \pm 0.10	164.23 \pm 0.08
CV%	0.04	0.06	0.05

5.3.5 PILOT STUDY - DISCUSSION

The primary objective of this pilot study was to determine the more appropriate of two available assessment methods for determining balance. The first of these, the force plate, has been the instrument of choice in numerous balance and gait research studies. In particular, many within the biomechanical disciplines regard the Kistler force plate as being the “gold standard” to which other methods can be compared. The second of these is the pressure platform and the fact that it has been developed more recently accounts for research being somewhat scarce, although this does not mean this method should be discounted. The outcome of this preliminary study is therefore discussed in light of both previous research and, due to the limited research on the latter piece of equipment, in terms of repeatability of force and Cartesian co-ordinates.

The first test recorded the mean mass of a 2kg weight (Table 6) and the co-ordinates of a pointed javelin (Table 8) that were placed on the surface of the Kistler force plate three times in rotation at five different points. The same protocol was repeated a week later to determine inter-week reliability. The mean mass of 2kg, or 19.61N, on the Kistler plate produced a reading of between 20.19 and 20.39N in week 1 and 19.85 and 20.20N a week later with a standard deviation of approximately ± 0.6 N. The co-ordinates resulting from placement of the javelin also varied from one week to the next by as much as 13.60mm in the x axis and 2.30mm in the y axis, recorded at the bottom marker, with standard deviations of all points up to ± 5.60 mm. As suggested by Ball *et al.* (1999) these data will include errors of some form, whether equipment, noise or quantisation, if not all three. In particular, in the “quiet” stationary stance, the

magnitude of force change will be small in comparison to the noise registered by each of the Kistler transducers. Furthermore, there will also be the increased error created when calculating COP with weight placement at one point rather than equally distributed between two points (Middleton *et al.*, 1999). This, however, will be a requirement of the next study that specifies a single-footed stance in its methodology and, as such, needs consideration during this preliminary work.

The same protocol as above, used on the *RScan* pressure plate, showed mean mass to have increased between 21% and 65% at each of the 5 marked points from weeks one to two (Table 7). One possible reason for this fluctuation in the absolute values of force could be the vast number of sensors in use and the polymer material that rests over the sensors used to calculate force. The co-ordinate data, on the other hand (Table 9), produced smaller differences between the weeks for most of the five markers with standard deviation < 0.05 . This would give it some advantage when calculating COP as the formulae involved rely on the accuracy of the x and y co-ordinates rather than the absolute force values.

Finally, the second test used 5 x 10kg plates (490.33N) in the centre of the Kistler followed by an additional 2kg to simulate a weight shift in one of four directions, giving a total of 52kg (509.95N). This was repeated 3 times in succession and intra-session data were considered. There still appeared to be a difference between the expected force at each point and the actual force recorded. One example (Table 10) involving the mass at the centre marker during trial 3, where 50kg produced a value of

498.03N and the 52kg shift to the bottom produced a force of 512.25N, as opposed to 490.33N and 509.95N respectively. Again, this may be due to the errors highlighted by Ball (1999) that often arise when using the force platform. The values given for mass using the footscan fluctuated so greatly (Table 11), even when the 50kg plates remained in the same location on the pressure plate, that the investigator abandoned the trial in order to obtain further information from the manufacturers.

5.3.6 PILOT STUDY - CONCLUSION

The measurement of sway and other methods of calculating COP rely upon x and y co-ordinates and not upon force. There are many known advantages to using the force platform, as there are disadvantages in using it for balance measures, particularly with respect to its relative errors. The pressure plate, on the other hand, has limited research to substantiate its use. Its advantage lies with the greater reliability and accuracy x and y produced in this pilot study. As such, the *RSscan* would therefore be the natural selection for the balance test of the second study.

5.4 METHOD – STUDY 2

Participants

Fifty-two adults comprising of 11 male and 41 female participants with an average age of 30 years participated in this study. Volunteers, randomly recruited from responses to a number of advertisements placed around the University campus (see appendix xxiii), were required to conform to a specified selection criteria. This excluded individuals who a) were not within the specified age band of 20-50 years of

age and b) had health issues that compromised their safety or the integrity of the results (such as pregnancy, ankle instability or vestibular disorders). However, it included participants in good general health that had not incurred any episodes of chronic back pain within the preceding 3 years in addition to those who, within that period, had succumbed to an episode that could be classed as chronic. The definition of “chronic” in this instance refers to the existence of pain for a minimum of 3 months.

Interested applicants were forwarded more detailed information concerning the nature, design and purpose of the study (see appendix xxv - xxvi). They were also asked to complete a HLQ that explored the existence of back pain within their medical history (see appendix xxiv). Stratified randomisation allowed the investigator to allocate the 116 volunteers who qualified under the terms of the selection criteria into two boxes according to back pain status. There then followed a blind draw from each box to randomly extract 26 names for each of the two sub groups; namely a control group and a chronic back pain group. This process resulted in 7 men with 19 women in the control and 4 men with 22 women in the back pain group. In order to reduce bias, the second investigator who conducted the tests, was blinded to group allocation status. Furthermore, participants were informed that because the study specifically investigated core strength and endurance, they were not to disclose their back pain status to the person taking the measurements. Likewise, the investigator was under instruction to consider all participants as possible back pain sufferers. The physical characteristics of the participants are listed in Table 14.

Table 14 – Physical characteristics of participants Study 2 (Mean ± s.d.)

GROUP	PARTICIPANTS (n)	AGE (Years)	HEIGHT (cm)	WEIGHT (kg)
BACKPAIN	26	33.2 ± 10.2	166.2 ± 7.9	66.1 ± 13.2
CONTROL	26	27.2 ± 7.0	169.0 ± 7.8	64.0 ± 12.1
TOTAL	52	30.2 ± 9.2	167.6 ± 7.9	65.1 ± 12.6

Informed consent, obtained from each participant prior to participation in testing (see appendix xxvii), included the rights of the participant to withdraw from the study at any point. In addition, it clearly stipulated the terms of the honorarium that upon completion of testing the participant would be entitled to the sum of £25. The study had been granted prior approval by the University Ethics Board, the requirements of which included a Health and Safety Risk Assessment to be carried out.

Experimental Procedure

The study was conducted at the Whitelands campus in Roehampton University, London. Volunteers were notified of their acceptance in the study by email along with confirmation of their group allocation. All concerns raised by individuals, including issues related to the study or its testing protocol, were addressed prior to the offer of an appointment for testing via email correspondence or telephone. A 90-minute session was booked for each individual in the biomechanics laboratory at Whitelands. The format for the session revolved around a battery of tests, performed in a pre-determined order and manner so as not to

discriminate between the two groups (see appendix xxviii - xxix). The investigator treated participants for both the experimental and control groups with the same care required by those with back pain. The tests were predominantly physiological although there were some anthropometric, biomechanical and psychological measures. The parameters listed incorporated height, body mass, balance, postural control, back endurance and abdominal endurance. These are now outlined below.

Measurements

Anthropometry

Body Mass and Height

SECA 705 digital scales (Vokel and Halke. Hamburg) were used to determine the mass of the participant to the nearest 0.1kg. Likewise, a Holtain (Dyfed) wall-mounted stadiometer was used to measure the height to the nearest 0.1cm. participants were required to wear light clothing with bare feet.

Biomechanical

Static Postural Control.

Static postural stability assessment was performed using a pressure distribution plate (RSscan International, Belgium) that had been calibrated against an individual with a known body weight. The “0.5m pressure distribution plate”, with a 525 mm x 365 mm measuring surface and an interface box, was connected to an IBM Thinkvision computer operating on a Windows 2000 system. Vertical

force measurements were based upon a matrix of pressure-sensitive polymer sensors.

Prior to the balance test, the researcher had established the participant's functional leg dominance according to criteria suggested by Hoffman *et al.* (1998). This consisted of a) kicking a ball between two cones 1m apart and 6m away from the participant; b) initiating a step up onto a raised platform 20cm high and c) stepping into balance when pushed with appropriate force from behind by the researcher, midway between the scapulae, thus resulting in a forward stepping motion. The leg used most in responding to each of the three tasks was then used for the Romberg single-leg stance in both the eyes-open and eyes-closed condition (Whitney, 2004).

The duration of each balance trial was 30 seconds during which the participant had to stand barefoot and upright on the pressure plate with arms folded across the chest and hands placed upon the opposite shoulder. This "30 seconds" was further subdivided into a 5-second delay, to get the participant settled into a comfortable starting position, a 20-second collection of balance data and a final 5-second countdown to test completion. The participant was directed to remain as motionless as possible throughout the trial. During the eyes-open condition they were required to focus upon a circle, 3cm in diameter, placed three meters in front at eye level. Prior to the eyes-closed condition the opportunity was available to undertake a practice trial to become familiar with the sensation and level of difficulty that standing on one foot with eyes closed creates. Criteria for termination of a trial by the researcher were if either hand lost contact with

the respective shoulder, if the eyes opened within the closed-eyes condition or if the raised leg touched the supporting leg or the ground. The participant had to attempt to complete three trials, each interspersed with 120-second rest intervals where a chair was provided to ensure consistent foot placement on the plate. There was a ceiling of ten trials for each condition.

The sampling frequency, set at 50Hz, gave rise to 998 data points for each of the eyes-open and eyes-closed trials. The additional 10-second countdown, five at either end of data collection, was designed to reduce sampling errors. The data were collected and displayed using the footscan 7x balance interface software (RSscan International). The average data for each parameter, evaluated from its set of three trials determined sway path, maximum displacement in the x -axis, maximum displacement in the y -axis and COP velocity. Romberg's coefficient, which distinguishes the impact visual contribution has on sway, was also established.

Dynamic Postural Control

A stabilometer (Model 16020, Lafayette instruments Inc., IN) platform measuring 106cm x 64cm was set to ± 13 degrees from the horizontal plane. Two non-skid surface pads 30.5cm x 46cm were mounted on the deck, 25cm apart on the base to reduce slipping. This was attached to a millisecond timer (Griffin, Loughborough) accurate to $\pm 0.1\%$. Participants were instructed to stand on the platform with a two-footed stance, each foot positioned on one of the rubberised rectangles, and to maintain a centred balance within 13 degrees of either side. Participants were given time to feel

comfortable on the equipment and a practice trial was encouraged. This was followed by three further trials of 30-seconds, determined by the use of a stopwatch, with trials interspersed by 90-second rest periods. The “time in balance” for each test was recorded and a mean calculated. The stabilometer task has been shown to be a reliable measure of balance (Araki, Mintah and Mack, Huddleston, Larson and Jacobs, 2006)

Physiological

Isometric trunk extensor endurance – Sørensen test (Biering –Sørensen, 1984)

The Biering–Sørensen test has been shown to be consistently reliable as a measure of back extensor endurance (Alaranta, Hurri, Heliovaara, Soukka and Harju, 1994; Latimer *et al.*, 1999). The participant was positioned prone at 0 degrees of lumbar flexion on an examining table with the upper edge of their iliac crests aligned with the top edge of the table. The lower body was secured to the table with three straps, located around the pelvis, knees and ankles respectively. Once in position the participant was permitted to rest the upper body on a stool placed directly below the unsupported segments until recording commenced. To perform the test the participant needed to fold their arms across the chest and maintain the upper body in horizontal alignment (see Fig. 1). The static hold-time during which the body remained in this horizontal position was observed and recorded with a maximum duration of 240 seconds.

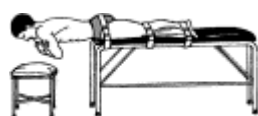


Fig. 1. The original Sørensen test.

Dynamic trunk endurance -abdominal

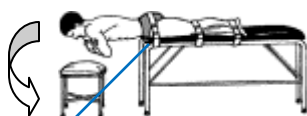
Abdominal endurance was assessed using the “abdominal curl conditioning test” (National Coaching Foundation, Leeds). The test, a progressive sit-up test, was conducted according to the instructions accompanying the pre-recorded audiotape. Curl-up tests have been shown to be a reliable field test for abdominal muscular endurance (Sparling, Millard-Stafford and Snow, 1997; Moreland, Finch, Balsor, Gill and Stratford, 1997). The participant was directed into a supine position on a padded exercise mat and a goniometer ensured knees were flexed between 70 and 90 degrees. Both arms were crossed over the chest and feet gently stabilised in place at a distance of approximately 5-8cm apart. The range of trunk movement required was from horizontal to vertical. The tape commenced with a 15-second warm-up routine followed by trunk stretches. This was followed by the abdominal curl test which required the participant to remain in a horizontal position for the first bleep as the timer was started, then perform a vertical movement up to 90 degrees on the second bleep and back to horizontal on the third. The sit-up movement was repeated until performance could no longer be maintained in terms of repetitions or range of movement, and the time recorded. Verbal motivation was provided to all participants in a similar manner as they began to tire.

Dynamic trunk extensor endurance

60-second back extension endurance test (Lanning *et al.*, 2006; Udermann *et al.*, 2003).

The prone position and alignment of the participant on the bench was identical to the Sørensen test with iliac crests at the edge of the examining table and the lower

body secured with straps. To ensure a resting position before commencement of the test, a stool was again used as an aid to support the upper body. However, unlike the isometric test, the hands were positioned behind the head and a line indicated by a length of string was provided from the bench to the floor at an angle of 45 degrees. The string provided the participant with a visual end marker for the range of motion required. The protocols consisted of lumbar flexion from the horizontal to this 45-degree position and back to horizontal (see Fig. 2). Each repetition required the participant to travel through the full range of movement with the number of complete repetitions performed within 60 seconds recorded for analysis. Upon completion of all trunk tests participants carried out a series of stretches. Dynamic extensor endurance tests have been shown to have acceptable interrater reliability (Moreland *et al.*, 1997).



Participant lowers upper body to the string marking a 45° angle.

Fig.2. Range of movement for dynamic trunk extensor test.

Psychological

QUEBEC

The QDS (Kopec *et al.*, 1995) is a 20-item self-administered instrument that investigates how back pain affects a participant's everyday activity at the time of completion (see appendix xxx). Test-retest correlations for items included within the scale were considered reliable and the questionnaire was shown to demonstrate high internal consistency (Kopec *et al.*, p155). It is designed on a 6-point Likert-type scale

of 0 to 5 and the higher the score the less the participant feels able to do because of their back pain. The questionnaire was administered at the start of the session, prior to any physical tests taking place.

Statistical analysis

GPOWER, using a large effect size $f = 0.8$, $\alpha = 0.05$, power = 0.8, dictated “total sample size” should be fifty-two participants. This number was assigned equally between recent chronic back pain sufferers and a non-back pain control group. The data for each variable, expressed in terms of their mean and standard deviation, were entered into a table format for both the back pain and the control group. All continuous data were tested for normality using the Shapiro-Wilk test to establish whether parametric or non-parametric statistical methods would be more applicable. Non-normal variables were then compared non-parametrically using the Mann-Whitney U-test. Experimental data were analysed on SPSS (version 15) using an independent t-test to determine differences between the two groups. Statistical significance of the main effects was set as $P < 0.05$. Correlation was determined using Spearman’s or Pearson’s as appropriate.

5.5 RESULTS

Normality tests detected a significant difference in the age, eyes-open balance and sit-up test of the control group. It also found significant differences in the normality of the eyes-open and eyes-closed balance data within the back pain group. This has influenced the use of non-parametric testing when assessing differences between the two groups for the above-mentioned parameters. Although, not required for comparison

between the groups, “age” would need greater consideration due to the effect upon other variables; $U = 215.50$, $P < 0.05$, $r = -0.31$. Upon further investigation, however, there was no correlation with any of the other measurements and so age data was not excluded.

Comparisons of anthropometric data are displayed in Table 15. Independent t-tests indicated there were no significant differences shown in baseline measures between the groups. Static and dynamic balance measures (Table 16) displayed no significant differences between the control and back pain group. The measures relating to trunk endurance were much more interesting. The “Sørensen” isometric trunk extensor test was significant $t(50) = 2.24$; $P < 0.05$, $r = 0.30$. The dynamic variation that involved the participant lowering the upper trunk segments by 45° before returning to horizontal was highly significant $t(50) = 3.79$; $P < 0.01$; $r = 0.47$. Finally, the abdominal curl test, found trunk endurance using the abdominal muscle groups to also be significant $t(41) = 3.10$; $P < 0.05$; $r = 0.44$.

Table 15. Anthropometric measures (mean \pm s.d.)

Parameter	Control group (n = 26)	Back pain group (n = 26)	P
Height (cm)	169.0 \pm 7.8	166.2 \pm 7.9	0.207
Body Mass (kg)	64.0 \pm 12.1	66.1 \pm 13.2	0.560
BMI	22.4 \pm 3.6	23.8 \pm 3.9	0.172

BMI, Body mass index

Table 16. Balance, posture & trunk endurance measures (mean \pm s.d.)

Parameter	Control group (n = 26)	Back pain group (n = 26)	P
Romberg-eyes open (mm)	519.2 \pm 173.7	556.2 \pm 182.5	0.370
Romberg-eyes closed (mm)	1050.5 \pm 271.8	1197.4 \pm 504.2	0.647
Dynamic balance (s)	18.4 \pm 4.2	18.6 \pm 3.9	0.852
Back Isometric (s)	141.1 \pm 51.0	107.0 \pm 58.4	0.030*
Back Dynamic	27.2 \pm 10.6	17.7 \pm 7.2	0.001**
Sit ups (s)	103.8 \pm 55.6	64.4 \pm 33.6	0.018*

* $P < 0.05$; ** $P < 0.01$.

Table 17. Psychological measures (mean \pm s.d.)

Parameter	Control group (n = 26)	Back pain group (n = 26)	P
QUEBEC	1.88 \pm 2.67	19.92 \pm 16.65	0.001**

** $P < 0.01$

Table 17 displays the highly significant result from the QDS self-evaluation questionnaire $U = 29.00$, $P < 0.01$, $r = 0.79$ which indicates how individuals perceive back pain to affect everyday aspects of their lives. The average score is approximately 2 for the twenty-six participants in the control group, but closer to 20 for the twenty-six participants in the back pain group.

Further investigation into the relationship between the variables found a correlation between isometric back endurance and dynamic back endurance ($r = 0.41$; $P < 0.01$, $r^2 = 0.17$), both of these with sit-ups ($r = 0.47$, $P < 0.01$, $r^2 = 0.22$; $r = 0.61$, $P < 0.01$, $r^2 = 0.37$) as well as the back pain questionnaire with dynamic back endurance ($r = 0.36$; $P < 0.01$, $r^2 = 0.13$) and isometric back endurance time ($r = 0.33$, $P < 0.05$, $r^2 = 0.11$).

Dependence on vision during the single-footed balance test was analysed using the Romberg quotient (RQ), which is the proportion of eyes-closed divided by eyes-open, which was calculated to be 2.14 ± 0.58 . This was calculated and showed that the mean “centre of force (COF) travelled way” with eyes-closed was more than twice the mean “COF travelled way” calculated for eyes-open.

5.6 DISCUSSION

The motivation behind this study was to investigate the difference in parameters that distinguish individuals with CLBP from those who have not experienced back pain (see page 139). It was designed in such a way as to allow selected physiological, biomechanical and psychological factors in a group of participants with CLBP and a second control group to be tested for differences. The variables selected were those that, based upon existing research, could influence the occurrence and intensity of such pain or affect the overall quality of life. This study also follows on from study one where the findings not only indicated exercise could be advocated as one of these remedies, but it

suggested further investigation into balance, posture, core strength and flexibility as a direction in which to develop research.

The starting point for discussion, as mentioned above, revolves around the physiological and biomechanical measures selected for investigation. Static balance, an indicator of postural control (Carroll *et al.*, 1993; Schumann *et al.*, 1995; Gerbino *et al.*, 2006), was calculated on a pressure plate as COF travelled way. This was measured using a single-footed stance with both Romberg eyes-open and eyes-closed conditions to determine differences in standing balance (Wolff *et al.*, 1998; Hasan *et al.*, 1990). Despite Hoffman *et al.* (1998) concluding there was no difference between a dominant and non-dominant leg the investigator chose to select the dominant leg for testing to reduce participant fatigue. The ratio of eyes-open to eyes-closed, was then used to assess the visual contribution of the single-leg trials. The resulting data showed the average “travelled way” of the trial to have doubled in the absence of visual feedback, which is in agreement with Onambele *et al.* (2007) and Perrin *et al.* 1999 who also depicted an increase. This study, however, highlights no significant differences between the back pain and the control group. These results conflict with similar studies by Mientjes *et al.* (1999) and Byl *et al.* (1988) who found a significant difference in the balance responses of the CLBP group and healthy control group. Dynamic balance also highlighted no differences between the groups, which again differs from the findings of studies such as Volpe *et al.* (2006).

The results of this study showed the CLBP group maintained a holding-time of 107.0 ± 58.4 seconds in the Sørensen test, which is significantly shorter ($P < 0.05$) than the control group with a holding-time of 141.1 ± 51.0 seconds. This corresponds to the findings of Tekin *et al.* (2009) and Latimer *et al.* (1999) who demonstrated that Turkish coal miners with low-back pain have shorter endurance times (99.9 ± 19.8 s) than their healthy counterparts (128.6 ± 15.2 s) and, in the latter study, that those participants asymptomatic to back pain had significantly longer holding-times. A review by Moreau *et al.* (2001) reported holding-time in healthy males of 84 to 195 seconds, healthy women 142 to 220 seconds, back pain men 80 to 194 seconds and back pain women 146 to 227 seconds. With 79% of participants in the current study being female, this may explain why the holding-time for healthy women in the review and study 2 are similar. However, the results for back pain female participants in these two studies do not agree and it is interesting how the results for Moreau *et al.* show a longer holding-time for female back pain participants than for female healthy participants. Concerning the modified dynamic trunk extensor endurance test used in the current investigation, this was highly significant ($P < 0.01$), with the back pain group achieving an average score of 18 ± 7 repetitions and the control group 27 ± 11 in the allocated 60 seconds. This differs vastly from Lanning *et al.* (2006), whose average score obtained by collegiate athletes using the same test was 53 ± 13 repetitions. Lanning *et al.* does not suggest that their study was conducted on either a non-athletic population or a control. Similarly, the results of the sit-up test in the current study ($P < 0.05$) showed back pain participants sustained a performance time 39 ± 22 seconds shorter than the control group. In essence, all three measures of endurance; namely holding-time, number of reverse curls in a minute and sit-up time, seem to

support an overall significant difference in trunk endurance between the two groups. However, the most pertinent disadvantage is that, irrespective of the efforts of the investigator to provide regulated levels of encouragement, participants appeared influenced by their own perceived levels of pain and motivation when expected to continue a test to fatigue.

The final area for discussion revolves around the QDS questionnaire, which has been recommended as an outcome measure in clinical trials (Kopec *et al.*, 1995). The use of this short 20-item self-evaluation form would help assess the level of functional disability in participants, with a higher score indicating greater disability. The results using Mann-Whitney displayed a significant difference producing a score of 1.9 ± 2.7 for the control group and 19.9 ± 16.7 for the back pain group. The questionnaire data also showed a high correlation with the isometric and dynamic back endurance tests ($P < 0.05$ and $P < 0.01$ respectively). This is in keeping with other studies that have found a correlation between functional disability scores and Biering-Sørensen hold-times (Tekin *et al.*, 2009)

5.7 CONCLUSION

The principal conclusion of this study supports the premise that individuals with CLBP are more likely to have weaker abdominal and back extensor endurance than non-back pain sufferers. It also reinforces the use of the self-evaluation “back disability outcome measure” as a means of determining the extent of that pain. Together these tools may prove influential when seeking to address ways of reducing chronic

recurrences and increasing the quality of life. It was not possible on this occasion to document significant changes in either static or dynamic balance between those with and without CLBP. This does not mean that mind-body type exercise, focusing on trunk musculature, would not influence balance and so further investigation into the effects of this measure following exercise are required.

Chapter 6

**An investigation into the Physiological and
Psychological Responses of Adults with Chronic
Low Back Pain: A 10-Week BodyBalance
Training Programme.**

2009

School of Human and Life Sciences
Roehampton University

Study 3 – The Effect of BodyBalance on Back Pain.

“We should not exercise the body without the joint assistance of the mind; nor the mind without the joint assistance of the body.”

Plato, 429-347BC

6.1 INTRODUCTION

The purpose of this thesis was to investigate the impact of core training and to determine whether it could prove beneficial to individuals afflicted by CLBP. The hypothesis, more specifically, attempts to establish whether trunk stabilisation could be influenced by participation in BodyBalance and if this in turn would have any impact on the level of pain experienced. Due to the number of issues that needed to be addressed, the investigation was broken down into three smaller studies. The first entitled “Physiological and Psychological Responses to a 12-week BodyBalance Training Programme” selected the exercise format to be used and investigated specific parameters based upon the claims purported by the company (LMI) designing and distributing the product in the mass market place. The advantage of this programme was its accessibility by the general public, both in the UK and worldwide, along with a clearly specified choreography that enhanced repeatability. This is in direct contrast to the mind-body programmes incorporated within BodyBalance, namely yoga, Feldenkrais, Pilates and tai chi, where each format varies in content according to the instructor and style of discipline. The main disadvantage of the programme was the lack of peer-reviewed research and the quality of studies available on its component parts. Study 1, conducted on 34 healthy adults aged (mean \pm *s.d.*) 43.9 ± 10.9 , demonstrated that significant

changes occurred after 12 weeks of participation. The most relevant were reductions in the waist and hip measurements, an increase in the maximal lower back strength and an increase in flexibility measures around the trunk. The conclusion was that BodyBalance as a programme would be a suitable choice to enhance core parameters around the trunk and as a result could prove useful in combating CLBP.

With a training programme decided upon there still remained the need to identify whether differences existed at the outset in relevant parameters between those with symptoms of CLBP and those with healthy backs. The second study “Investigating Measures of Postural Control & Trunk Endurance as Indicators of Chronic Low Back Pain” set out to investigate precisely this. Examining data from 52 participants aged 30.2 ± 9.2 years, divided equally between a low-back pain group and a healthy back control group, it started to explore differences in trunk endurance, postural control and balance in addition to the extent of back pain endured by individuals. The results of this study reinforced the concept that distinct differences did exist for measures of abdominal and lumbar extensors along with perceived levels of pain. It also established a correlation between these factors.

With BodyBalance labelled as a suitable training programme for trunk stabilisers and CLBP individuals experiencing weaker abdominal and back extensor endurance it seemed a logical progression to investigate whether a longitudinal course of BodyBalance training would help alleviate the symptoms associated with low-back pain. Back pain consists of a perceived element that is subjective according to the psychological make-up

of each individual. It has also been shown that, with back pain participants, the perception of expected pain can differ from the actual level of pain experienced (Crombez, Vervaeke, Baeyens, Lysens and Eelen, 1996). Ultimately, if perception is so important, it made sense to consider incorporating some descriptive research techniques alongside quantitative analyses, to enhance the quality and richness of the findings from this study.

The research question identified in study three is “to investigate the effect of BodyBalance on chronic low-back pain sufferers”. The experimental aim anticipates that the level of CLBP experienced will diminish and that trunk endurance will be enhanced through participation in such a treatment. Due to the nature of pain, both questionnaires and interviews will be used to supplement experimental data. The findings of this study will be influential in deciding whether BodyBalance and similar mind-body exercise programmes should be promoted as a means of addressing the battle against back pain.

6.2 LITERATURE REVIEW

The purpose of this literature review is to consolidate and update the research discussed in the first two studies and provide a more comprehensive insight into any remaining areas as dictated by the current investigation. Study 1 discussed the background to BodyBalance and investigated the many claims that supported the idea behind its conception. These claims were not directly linked to the workout itself, but to the mind-body programmes whose moves had been included within its structured

choreography. The focus area frequently touched upon the components of fitness and balance as well as upon stress, anxiety and mood states. Next, study 2 went on to discuss literature concerning various aspects of postural control tests, trunk endurance tests and back pain disability questionnaires. Study 3 will now seek to elaborate on earlier research, with particular topics for consideration including the impact of exercise on core areas along with effects on trunk endurance, flexibility, body mass, balance and perceived back pain.

Exercise is often advocated as a means of strengthening the body and improving fitness. A literature review on exercise and back pain (Henchoz and Kai-Lik So, 2008) suggested exercise to be effective in the primary and secondary prevention of low-back pain as well as being a treatment that “diminished disability and pain severity” (p533). A second review on exercise as a treatment modality for CLBP (Rainville, Hartigan, Martinez, Limke, Jouve and Finno, 2004) again found evidence in favour of exercise for acute or chronic back pain with results indicating either no change or a reduced risk of future back pain. It categorised the purposes of exercise to be to enhance flexibility, strength and endurance alongside reducing the intensity of pain and back pain related disabilities, particularly those disabilities related to the fear and concern of pain. A third literature review (Bigos, Holland, Holland, Webster, Battie and Malmgren, 2009) analysed trials that had focused on preventing back pain in adults. From within the 20 “high-quality controlled trials” (p147) selected that conformed to the inclusion criteria, seven of the eight exercise intervention trials were found to be effective in preventing back pain. These consisted primarily of strength and flexibility programmes, particularly

those surrounding abdominal and back extensor muscles. It was suggested that the exercise trial found not effective had “low statistical power” due to insufficient participants. The remaining twelve studies, which included education, lumbar supports and shoe inserts, produced negative results. Additionally, many other studies such as Batt and Todd (2000) or Jacob, Baras, Zeev and Epsein (2004) have also been shown to support the relationship between participation in exercise programmes and a decline in CLBP measures investigated. It should be noted that often population groups are generalised and various other factors could have influenced results.

A variety of fitness components and principles of training have been selected as the focal point of CLBP research connected with exercise. Henchoz *et al.* (2008) highlighted the need for future research to establish optimal time, type and frequency of exercise programmes required for the prevention or treatment of back pain. An investigation by Cady, Biscoff, Eugene, O’Connell, Thomas and Allan (1979) looked at the strength and flexibility of fire fighters and found the fitter they were, the less chance they would succumb to back injuries. A further study by Slade, Ther and Keating (2006; p163), that reviewed thirteen “high-quality controlled trials” relating to the effect of back strengthening exercises on people with low-back pain, also suggested the type of exercise to be an important factor. They concluded that trunk strengthening appeared more effective than no exercise for reducing pain and improving function. Finally, a review of physical activity, fitness and low-back pain by Plowman (1992) discussed research investigating the relationship of low-back pain, trunk strength, trunk endurance and flexibility. The study (p233) suggested that “at face value” the eight studies reviewed

showed a link between the four variables, although the author advised some caution in interpreting the findings. Lederman (2010) on the other hand, presented a different picture with an interesting critical review on the concept of CS that opposed the perspective described above. He argued that a number of assumptions surrounding the topic relied heavily upon the connection between abdominals and a strong back. Particular interest rested upon the general belief that “weak abdominal muscles lead to back pain...strengthening abdominal or trunk muscles can reduce back pain [and] that there is a relationship between stability and back pain” (p84). Assessing a number of studies, he highlighted investigations that did not support these assumptions. This included back pain research that resulted in non-significant findings following “strength” intervention programmes and investigations that displayed no significant relationship between CS and an improvement in low-back pain. Lederman concluded that weak trunk and abdominal muscles should be regarded as a normal variation rather than “pathology” in addition to “weak or dysfunctional abdominal muscles will not lead to back pain” and “core stability exercises are no better than any other form of exercise in reducing chronic lower back pain” (p94). Therefore, with the findings of some investigations suggesting trunk strength, endurance and flexibility could be considered appropriate measures for low-back pain and Lederman’s suggestion that this is largely based upon assumptions, it would be useful to look at literature concerning tests for these parameters before selecting the final battery for the current study. More specifically, literature regarding abdominal curls, the sit-and-reach test, Sørensen test, McGill’s tests, body composition, mass and balance will now be discussed, followed by back pain disability questionnaires.

Abdominal endurance is often assessed using sit-up style tests. Porcari, Miller, Cornwall, Foster, Gibson, McLean and Kernozek (2005) conducted a study using 32 adults, 24 undergoing neuromuscular stimulation on their abdominal muscles and 16 providing a control. Both groups refrained from engaging in any other exercise for the 8-week duration of the study. Training for the experimental group took place 5 days per week with each session lasting between 20-40 minutes. This produced a significant improvement in muscular endurance as determined by the ACSM curl-up test with the experimental and control showing a 100% increase and 28% increase respectively. There was the suggestion that the increase in the control group may have been partly attributable to “a learning effect” and the 28% was therefore subtracted from the experimental results to yield a net improvement of 72%. However, if there is an effect of familiarisation gained from repetition, the implications of incorporating the ACSM test in “repeated measures” studies may need to be considered. Similar findings were noted in a study by Knudson (2001) who tested the “bench trunk curl” on 44 young adults and found a significant correlation with abdominal endurance ($r_{\text{male}} = 0.50$ and $r_{\text{female}} = 0.46$; $P < 0.05$). Likewise, Herrington and Davies (2005) divided 36 asymptomatic females equally between a Pilates group, an abdominal curl group and a control group. The authors concluded that those participants taking part in Pilates for 6 months were able to contract the abdominals and maintain better lumbo-pelvic control than those in the other groups. However, there is some discrepancy between the two intervention groups as the Pilates group attended one or two 45-minute classes per week over 6 months whilst the abdominal group attended one or two 15-minute classes per week over the same period.

A field test designed to measure hamstring and low-back flexibility that is often included in many health-related fitness test batteries is the sit-and-reach test. There is a generalised belief that maintaining hamstring and low-back flexibility may prevent acute and chronic musculoskeletal injuries including those relating to the lower back. Existing research for the standard sit-and-reach test indicates reliability to be consistently high (Baltaci, Un, Tunay, Besler and Gerçeker, 2003). A pilot study by Galantino, Bzdewka, Eissler-Russo, Holbrook, Modck, Geigle and Farrar (2004), exploring the effect of six-weeks of hatha yoga on back pain, used a functional reach test and sit-and-reach test on twenty-two back pain participants. Their outcome showed an improvement in these measures, although the research was not powered to be statistically significant. A similar study by Cowen (2010) explored the effects of yoga on 108 healthy fire fighters of whom 77 completed baseline and post intervention assessments. Flexibility was measured using a sit-and-reach test. Findings, based on an average participation of four classes, revealed significant improvements in trunk flexibility as calculated using a paired t-test ($P < 0.01$). In addition, Cowen and Adams (2005) conducted a pilot study on 26 adults participating in six weeks of either hatha or ashtanga yoga. In “partial curl repetitions” and the sit-and-reach test they displayed a significant improvement in both trunk endurance and flexibility. Finally, a study by Sekendiz *et al.* (2007) tested the effects of three classes of mat-based Pilates for five consecutive weeks on trunk strength, endurance, and flexibility on sedentary females; eighty percent of the participants had experienced low-back pain on at least one occasion. Significant differences ($P < 0.05$) were found between the Pilates and the control group for the following variables: a) abdominal and lower back strength assessed on a dynamometer, b) abdominal endurance measured using the crunch

test and c) posterior trunk flexibility determined with the sit-and-reach test. Despite Sekendiz *et al.* producing favourable results, an appraisal of Pilates research literature by Bernardo (2007; p106) concluded that there was only “cautious support for the effectiveness of Pilates in improving flexibility, abdominal and lumbo-pelvic stability and muscular activity” due to the weaknesses and limitations of available research.

A number of measures have been developed to assess trunk extensor, flexor and oblique muscle endurance. These have appeared particularly useful in studies investigating low-back pain. The Sørensen test, designed to measure time to fatigue for the back extensors, has already been shown to have reasonable test-retest reliability (Biering-Sørensen, 1984). Simmond, Olson, Jones, Hussein, Lee, Novy and Radwan (1998), when testing 44 low-back pain participants against 48 pain-free participants, also supported the use of the Sørensen test amongst other “physical performance” tasks to complement patient self-report instruments. Lanning, Uhl, Ingram Mattacola, English and Newsom (2006) used a dynamic variation of the Sørensen, the 60-second back-extension endurance test, on 105 healthy athletes who achieved (mean \pm *s.d.*) 53 ± 13 repetitions. In addition to this, the McGill’s tests that assess trunk muscle endurance proved reliable with coefficients of > 0.97 for both lateral and isometric flexor tests when repeated on 5 consecutive days and again eight weeks later (McGill, Childs and Liebenson, 1999). The McGill lateral flexor musculature test is basically a timed side-bridge (McGill, 2007) and McGill *et al.* (1999) demonstrated there was no significant difference in endurance times between the side-bridge performed on a healthy individual’s left or right side. Likewise, Evans, Refshauge and Adams (2007) found

performance on the left and right side-bridge to be strongly correlated ($r = 0.86$, $p < 0.01$). The trunk endurance tests listed above could also help determine imbalances in opposing muscle groups. In this manner, McGill, Grenier, Bluhm, Preuss, Brown and Russell (2003) found a reduced trunk extensor capacity relative to trunk flexors and lateral musculature in people with a history of CLBP.

Articles in the press often advocate “exercise” programmes as a method of inducing weight loss or maintenance. This is a somewhat generalised proposal, as the benefits of each programme will vary depending upon its composition. Mind-body programmes, for example, will probably not have an effect on weight. This has been supported by many longitudinal studies on Pilates and Feldenkrais where no significant changes in body composition or weight were noted (Segal *et al.*, 2004; Sekendiz, Altun, Korkusuz and Akin, 2007; Gutman *et al.*, 1997). However, there are at least two studies (Jago *et al.*, 2005; Benavides and Caballero, 2009) conducted on children between 8 and 15 years taking part in either a longitudinal Pilates or ashtanga yoga programme, where significant weight or BMI differences were discovered between the exercise and control groups. This would suggest the possibility of other factors influencing the outcome rather than the type of exercise programme followed. If weight loss is not the motivation then exercise must be pursued for other reasons. One study on Pilates (Sperling *et al.*, 2006, p328) found the majority of followers to be primarily “middle-aged women who did not participate regularly in other exercise activities and who had some complaint of musculoskeletal pain”. Likewise, yoga has been shown to be a good option for participants wanting to enhance muscular fitness and flexibility (Clay *et al.*, 2005).

Balance has often been connected to research in low-back pain, consequently playing an important role when considering the future of mind-body exercise upon individuals suffering from this condition. However, only a limited number of studies currently exist with these parameters. One reason for this may be that the testing protocol for balance could induce pain or discomfort to low-back pain patients (Mientjes *et al.*, 1999). The first investigation of interest is Johnson, Larsen, Ozawa, Wilson and Kennedy (2007) who studied the effects of Pilates on 34 healthy adults, equally apportioned between an exercise and control group. The Pilates group participated in 10 sessions over a five-week period whilst the control group did not participate in Pilates and were required to maintain the activity level recorded at “pre-test” for the duration of the investigation. Using the functional reach test as a measure of dynamic balance, the investigators found a significant change in the Pilates group only, thus concluding dynamic balance was improved through practising Pilates. However, the functional reach test is dependant to some extent on self-motivation when used as a measure of balance (Emery, 2003; p496). A further influential factor for balance is age, as younger participants tend to perform better on balance tests than the older population (Wiksten *et al.*, 1996; Koceja, Allway and Earles, 1999; Gutman *et al.*, 1997). Likewise, postural control has been found to be better in participants that had always practised or at least until recently practised forms of physical and sporting activities (Perrin *et al.*, 1999). One study on low-back pain participants by Gill and Callaghan (1998) extended the work on proprioceptive deficits in individuals with back pain to include spinal proprioception. The study included 20 individuals with back pain and 20 without who were required to reproduce a target position. Their findings showed that significant differences in

proprioception existed between the low-back pain and pain free groups. A later study by Nelson-Wong and Callaghan (2010) showed the gluteus medius and trunk muscle co-activation to be a predisposing factor in low-back pain development when associated with static standing. This co-activation of the muscles was demonstrated during the 2-hour standing test prior to reports of pain development.

The final area to be discussed in the literature review for this study is research that has utilised pain disability questionnaires to gain information on the effects of back pain. To begin with, exercise is regarded as a way of reducing the intensity of low-back pain and reducing pain related disability through both physical changes along with desensitising a sufferer's fears and concerns (Rainville *et al.*, 2004). Verbunt, Seelen, Vlaeyen, van der Heijden and Knottnerus (2003) used the RMDQ (Roland *et al.*, 1983) to test the assumption that the fear of injury would lead to disability in patients with CLBP. Findings assessed on 40 patients with CLBP displayed a strong association between fear of injury and perceived disability. According to the fear-avoidance model (Vlaeyen and Linton, 2000; p329), acute back pain could create a fear of movement or (re)injury, which would cause them individually to avoid physical exercise. The assumption that this would result in a deconditioning effect was not confirmed by this study, although the authors suggest this may be due to a cross-sectional rather than longitudinal study design. There is also the issue of self-reported measures being subject to a difference between perception of pain and actual pain (Crombez, *et al.*, 1996). This suggests that the extent of pain experienced at the point of questionnaire completion may not necessarily be the same as "usual pain", which can be described as the average

intensity of pain experienced over a specified period of time (Jensen and McFarland, 1993).

Two questionnaires often used for CLBP assessment are the OLBDQ (Fairbanks *et al.*, 1980) and the QDS (Kopeck *et al.*, 1995). These have already had some mention in study 2, as has their acceptable level of test-retest reliability. There is satisfactory correlation between the QDS and OLBDQ (Enebo, 1998; p31). Both questionnaires require about five minutes each to complete and have been shown to be sufficiently reliable and sensitive enough to detect smaller changes in function and disability (Davidson *et al.*, 2002). The QDS evaluates the perceived impact of performing common activities required in daily life. It uses a Likert scale that goes from zero, being “not difficult at all”, to five that would be “unable to do” on a series of 20 questions. Total scores range from 20 to 100 with the higher score indicating greater disability. The OLBDQ again determines what daily activities have been influenced by the perceived experience of pain. Ten items describe pain along with the impact on a range of zero to five; the higher the value, the greater the impact. The score is the sum of all sections, or pro-rata if not all questions are answered, expressed as a percentage of the possible maximum score. A moderate disability ranges from 21% - 40%, a severe disability is 41% to 60%, “crippled” from 61% to 80% and above 80% suggests the individual bed-bound or exaggerating their symptoms (Fairbanks *et al.*, 1980). Mientjes *et al.* (1999) in a study with 8 low-back pain participants and 8 healthy controls showed the low-back pain participants to register 18% to 64% (score of 9 to 32) on the OLBDQ, so a minimal to severe disability respectively. In addition, Galantino *et al.* (2004), using the OLBDQ,

explored the influence of yoga on low-back pain participants ($n = 22$). The yoga intervention group attended two sessions per week for 6-weeks, whilst the control group received “no treatment” during this period. Findings showed a decreased perceived disability for the intervention group. The authors stated that the outcome supported the “need for more research investigating the effect of yoga for this population” (p59).

6.3 METHOD

Participants

A cluster of 15 adults with CLBP, 1 male and 14 female, participated in the study. Volunteers were recruited through a variety of sources (see appendix xxxi- xxxii). There was a limited response to three thousand flyers distributed within a two mile radius of the college ($n = 2$) or the physiotherapy practices contacted who were based in London as well as at Whitelands College ($n = 1$). Likewise, an advertisement on the social website with “Gumtree” gained enquiries but no suitable applicants. The remaining volunteers were selected from the response to a further 500 flyers placed around the campus, a notice on the University’s web pages and posters placed on college notice boards ($n = 12$). All interested applicants were sent a basic information pack about the study along with a HLQ (see appendix xxxiii) requesting details of their health, lifestyle and back pain. Despite 41 volunteers, only 15 fulfilled the criteria due to specific requirements of the study. Excluded were individuals who: (a) were currently, or had within the preceding 3-month period, participated in mind-body programmes; (b) were younger than 18 years of age; (c) had suffered from any medical or physical conditions that would influence the integrity of the results or compromise safety during the BodyBalance

treatment (such as specific balance disorders, spinal surgery or ankle, knee and hip problems). Inclusion into either group required the presence of back pain in the lumbar region for a minimum duration of 3-months within the preceding three years. Two individuals had specified medical conditions that caused concern; therefore, written confirmation was sought from their GP or physiotherapist to confirm their ability to participate.

Volunteers were randomly assigned to either a control lecture group (n = 7) or the exercise intervention group (n = 8) via a blind draw of names from a box. They were notified of their allocation by either email or letter and a date for the first testing session was mutually agreed. One of the fifteen participants did not complete the study due to pregnancy and medical concerns. The physical characteristics of the remaining participants (n = 14) are listed in Table 18.

Table 18 – Physical characteristics of participants who completed study 3
(Mean ± s.d.)

GROUP	PARTICIPANTS (n)	AGE (Years)	HEIGHT (cm)	WEIGHT (Kg)
EXPERIMENTAL	7	31.4 ± 8.3	167.4 ± 5.7	64.5 ± 9.4
CONTROL	7	42.6 ± 12.3	165.1 ± 6.5	67.7 ± 13.4
TOTAL	14	37.0 ± 11.6	166.3 ± 6.0	66.1 ± 11.2

From the fifteen participants half were invited at random to participate in a short twenty-minute interview. On this occasion, the selection process was stratified followed by a random draw to ensure a balanced distribution.

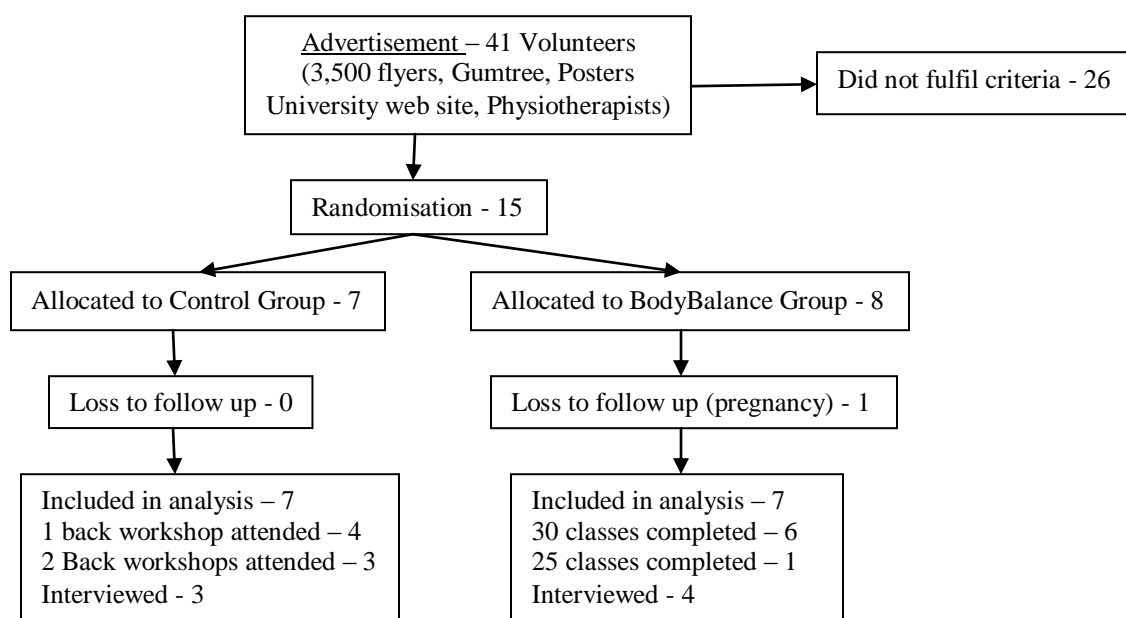


Fig. 3. Participant's flowchart through duration of study.

All participants provided written informed consent before participating in the study (see appendix xxxiv- xxxv), which had prior approval by the University Ethics Board. The informed consent included the rights of the participants to withdraw from the study at any stage along with the terms of the honorarium. This provided the experimental group participants with £100 and the control group with two physiotherapy sessions upon completion of both testing sessions and either 30 BodyBalance sessions or 2 back workshops accordingly.

Experimental Procedure

The testing sessions occurred at Whitelands College, Roehampton University in London. All participants taking part in the study were asked to maintain their current level of physical activity, which would be supplemented by BodyBalance if they had been allocated to the exercise group. A timetable was used to schedule baseline evaluation tests in the first 4 weeks, the intervention sessions over the 10-consecutive weeks following a three-week Christmas break and post-intervention tests in the subsequent 2 weeks. Prior to testing, individuals had the opportunity to clarify any concerns they may have had about the study or testing protocol. Assessments took the form of individual 120-minute sessions conducted in the SPARC laboratory. At both the preliminary and post-intervention sessions, each participant undertook a battery of tests, in a predetermined order, aimed at establishing physiological, anthropometric, psychological and biomechanical measures (see appendix xxxvi). The parameters included within the series were height, body mass, static balance, dynamic balance, flexibility, trunk endurance, back strength and back pain disability questionnaires. In addition, a selection of participants from each group (control $n = 3$, exercise $n = 4$) completed a 20-minute interview with the investigator at both testing sessions to enhance the information gained from the questionnaires. Outlined below are the contents of the test battery.

Measurements

Body Mass and Height

SECA 705 digital scales (Vokel and Halke. Hamburg) were used to determine the mass of the participant to the nearest 0.1kg. A Holtain (Dyfed) wall-mounted stadiometer was then used to measure the height to the nearest 0.1cm. Participants were required to wear light, comfortable clothing and stand in bare feet.

Biomechanical

Static Postural Control.

Static postural stability assessment was performed using a pressure distribution plate (RSscan International, Belgium) calibrated against an individual with a known body weight. The “0.5m pressure distribution plate”, with a 525 mm x 365 mm measuring surface and an interface box, was connected to an IBM Thinkvision computer operating on a Windows 2000 system. Vertical force measurements were based upon a matrix of pressure-sensitive polymer sensors.

Prior to the balance test, functional leg dominance was established according to the criteria suggested by Hoffman *et al.* (1998). This consisted of a) kicking a ball between two cones 1m apart and 6m away from the participant; b) initiating a step up onto a raised platform 20cm high and c) stepping into balance when pushed out of balance with appropriate force from behind by the researcher. The leg initiating most of the responses to each of the three tasks was selected for the Romberg single leg stance in both the eyes-open and eyes-closed condition (Whitney, 2004).

The duration of each balance trial was 30 seconds, during which the participant had to stand barefoot and upright on the pressure plate with arms folded across the chest and hands placed upon the opposite shoulder. This “30-seconds window” included a 5-second delay, a 20-second data collection period and a further 5-second countdown to completion. Soft mats were placed in the area surrounding the plate to enhance safety. The participant was directed to remain as motionless as possible throughout each trial. During the “eyes-open” condition, focus was directed upon a circle 3cm diameter three meters in front at eye level. Prior to the “eyes-closed” condition, there was an opportunity to perform a practice run. This familiarised the participant with the sensation and increased difficulty that would be encountered. Criteria for termination of a trial by the researcher included loss of hand contact with the respective shoulder, eyes opened within the closed-eyes condition or the raised leg resting on the supporting leg or ground. The participant aimed to complete three trials, interspersed with 120-second rest intervals where a chair was provided to ensure foot placement on the plate remained constant. There was a ceiling of ten trials for each condition.

The sampling frequency, set at 50Hz, gave rise to 998 data points for each of the eyes-open and eyes-closed trials. The 5-seconds delay at either end of the data collection period was designed to reduce sampling errors. Data were then collected and displayed using the footscan 7x balance interface software (RSscan International). The average data from three trials per parameter was used to determine sway path, maximum displacement in the x -axis, maximum displacement in the y -axis and COP velocity.

Dynamic Postural Control

A stabilometer (Model 16020, Lafayette instruments Inc., IN) platform measuring 106cm x 64cm was set to ± 13 degrees from the horizontal plane. Two non-skid surface pads, 30.5cm x 46cm, were mounted on the deck 25 cm apart on the base to reduce slipping. The platform was attached to a millisecond timer (Griffin, Loughborough) accurate to $\pm 0.1\%$. Participants were instructed to maintain a two-footed stance on the platform ensuring balance remained within 13 degrees of horizontal at either side. A practice trial preceded three trials of 30-seconds, each interspersed by a 90-second rest period. The “time in balance” for each trial was recorded and the mean calculated.

Physiological

Strength and Endurance

Isometric trunk extensor endurance – Sørensen test (Biering–Sørensen, 1984)

The participant was positioned prone at zero degrees of lumbar flexion on an examining table. The upper edge of their iliac crests was aligned with the top edge of the table. The lower body was then secured to the table with three straps, located at the pelvis, knees and ankles respectively. A stool was placed directly below the unsupported upper body segments to allow the participant to rest before testing. Upon commencement of the test, the participant maintained the upper body isometrically in horizontal alignment with arms placed across the chest. The static hold-time in this horizontal position was observed and recorded with a maximum duration of 240s.

Dynamic trunk endurance -abdominal

This “bleep test” (National Coaching Foundation in Leeds, 1992), involved sit-ups performed in time to pre-recorded audio tape. The tape was calibrated in accordance with instructions, which required the timing of a 60-second gap between the first two bleeps. The movement was initiated with the participant in a supine position on an exercise mat (thickness 0.8cm), knees flexed between 70° and 90°, feet approximately 5-8cm apart, arms crossed over chest and feet gently pressed down to the ground by the investigator as anchorage. The tape commenced with a 15-second familiarisation section followed by trunk stretches. This was followed by the abdominal curl test itself, which instructed the participant to remain in a horizontal position for the first bleep as the stopwatch was started, then perform a vertical movement up to 90 degrees on the second bleep and back to horizontal on the third. The frequency of repetitions increased after each minute. Encouragement was provided to ensure sit-ups were continued for as long as possible, ending only when the participant was unable to continue at the required speed or with full ROM and safe technique. At this point, the tape was stopped and time recorded.

Dynamic trunk extensor endurance- 60-second back extension endurance test

(Lanning *et al.*, 2006; Udermann *et al.*, 2003)

The equipment set up of this test, along with the position and alignment of the participant on the bench, was identical to the Sørensen test. Unlike the Sørensen, the hands were positioned behind the head and a length of string provided a visual reference from the bench to the floor at an angle of 45-degrees. The protocol called for lumbar

extension from horizontal, down to 45-degree angle and back to horizontal. Each repetition required the participant to travel through the full range of movement and the number of complete repetitions performed within 60 seconds was recorded for analysis.

McGill lateral musculature test

Reliability for the lateral musculature test has been shown to be good with reliability coefficients of 0.99 (McGill *et al.*, 1999, p943). The participant was instructed to lie on their side on a mat (thickness 0.8cm) with legs extended. The researcher demonstrated the correct alignment of shoulders, hips and ankles followed by elbow placement that lay directly below the shoulder of the lower arm. Supporting themselves on the elbow and feet, the participant raised the hips off the mat and maintained a straight line over their full body length. Encouragement was given to maintain this position for as long as possible. Once the straight-back position was lost and the hip returned to the exercise mat the time in the side-bridge position was noted.



Fig. 4. Side-bridge

Mc Gill flexor endurance test

The flexor endurance test has been shown to be reliable as a measure of endurance with reliability coefficients of 0.97 (McGill *et al.*, 1999, p943). The participant positioned themselves in a seated position with their back supported against

the surface of a wedge-shaped box angled at 55°. Hips and knees were flexed to 90° and arms were folded across the chest with hands placed upon the opposite shoulder. Timing commenced when the supporting wedge was moved away from the participant by 10cm. Feet were anchored gently to the floor by the researcher and encouragement was provided to ensure this isometric position was held for as long as possible. Once any part of the participant's back made contact with the box the time was recorded.

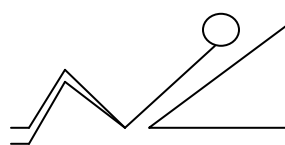


Fig. 5. Flexor endurance test

Back Strength

The test to determine the isometric strength of the back adhered to the protocol listed within the Takei Test Manual accompanying the “back dynamometer” (Takei & Company Limited, Tokyo). The measuring accuracy of the unit was given as $\pm 3\text{kgf}$ in 150kgf. The participant was required to stand on the dynamometer footplate, holding a bar attachment with a natural overhand grip. The length of the chain was adjusted to allow 30° of forward flexion. From this starting position, they were then to return gradually to an upright stance without incorporating any knee flexion. The participant was encouraged to perform a practice trial in advance of the test. Three trials were conducted, interspersed with one-minute rest intervals, following which the best result was used for analysis.

Flexibility

Modified sit-and-reach test

The modified sit-and-reach test protocol (Hoeger, 1989) was used to assess trunk and hamstring flexibility. A 12-inch high sit-and-reach box was placed close to a wall and the participant seated themselves on the floor between the box and the wall. Their buttocks, shoulders and head maintained contact with the wall whilst both feet were placed on the front surface of the box and arms were outstretched in front. A yardstick measured the distance of fingertip to box as an estimate of limb length. The participant was instructed to slide the hands along the superior surface of the box, in a slow and controlled manner, pushing a rule with the fingertips that was placed on top of the box at right angles to the participant. At the furthest attainable point, the position needed to be held for two seconds. The best of three trials was noted for analysis.

Range of Motion

A clinical goniometer (Medical Research Limited, Leeds), given as accurate to $\pm 1^\circ$, was used in this study to determine levels of trunk flexibility. All measures were repeated three times and the average for each test used to provide four measures of flexibility. All trials required stabilisation of the pelvis by the researcher to prevent unwanted rotation and each test using a clinical goniometer was preceded with it being aligned to zero on a horizontal surface. The three tests assessing hip joint ROM required the participant to be positioned on a physiotherapy bench. To test for hip flexion the participant was arranged supine on the bench with the clinical goniometer placed just above the patella of the right leg. They were then instructed to raise this leg as far as

possible towards the trunk, flexing at the knee to maximise ROM, whilst ensuring the left leg maintained contact with the table. The angle measured by the goniometer was then recorded. Staying supine, hip abduction was the next measure. A long-armed goniometer was placed on the anterior surface of the pelvis with one arm in line with the ASIS and the other arm directed downwards towards the patella of the right leg. The participant was told to abduct the right leg slowly away from the body and stop when instructed. The researcher recorded the angle at the point hip rotation began to occur. The third measure, hip extension, called for the participant to lie prone with a clinical goniometer placed on the right hamstring, superior to the knee joint. The participant raised the leg in a controlled manner, avoiding knee flexion and ensuring their pelvis at the level of the ASIS did not lose contact with the bench. The final test, to assess thoracic and lumbar lateral flexion, involved the participant starting from an upright stance, arms hanging down alongside the body with a goniometer placed vertically upon the right shoulder at the point of the acromion process. The participant was instructed to retain pelvic stability in the sagittal plane whilst moving their right hand down the lateral aspect of the right thigh as far as possible. The angle was then recorded.

Psychological

QUEBEC BACK PAIN DISABILITY QUESTIONNAIRE

The QDS (Kopeck *et al.*, 1995) is a 20-item, self-administered instrument that investigates how back pain affects a participant's everyday activity at the time of completion (see appendix xxx). It is designed on a 6-point Likert-type scale of 0 to 5 and the higher the score the less the participant feels able to do because of their back

pain. The questionnaire was administered at the start of the session, prior to any physical tests taking place.

OSWESTRY LOW BACK PAIN DISABILITY QUESTIONNAIRE

The OLBDQ (Fairbanks *et al.*, 1980) was administered immediately after the QDS and before any physical tests. It is a questionnaire that shows satisfactory test-retest reliability (Enebo, 1998; p27; Triano, McGregor, Cramer and Emde, 1993; p70) and is divided into ten sections, each with six choice statements indicating a range of disability from minimal to severe. These, like the QDS, are rated on a Likert-type scale from 0 to 5. The participant was asked to select one of the statements per section. The disability in percent = (sum of all points for the ten sections)*100/50, although this may be pro-rata if not all sections were answered. The higher the percentage calculated, the greater the disability.

Activity

Experimental Group

For the ten-week duration of exercise intervention, the experimental group was required to attend BodyBalance in a leisure-centre studio within close proximity to the Whitelands campus. The leisure centre possessed the necessary licence to hold such classes on their premises. There were three sessions per week, conducted on a Monday, Wednesday and Friday lunchtime, each lasting 60 minutes. Three qualified BodyBalance instructors were recruited to take the sessions, which helped add some variety as each had their own motivational and teaching style. They were also allocated a specific day, yet

available to cover the other two instructors as and when necessary. All three possessed adequate Public Liability Insurance, appropriate music licences and were clearly advised of the back pain disability within the group. They were required to offer the alternative “easier” options advised by Les Mills in conjunction with the given movement. The choreography was standardised by following BodyBalance 43 (Table 19) to ensure the same movement components were included in each session.

Table 19 - Breakdown of BodyBalance 43 Choreography

Track	Mins.	Objective	Main Composition
1	3:46	Warm up	Tai chi, breathing, centering
2	5:24	Sun Salutations	Mountain pose, down dog, plank, crocodile, lunge
3	5:04	Standing Strength	Warrior & intense pose
4	3:50	Balance	Star pose & aeroplane pose
5	6:09	Hip Openers	Kneeling lunge, mudra, quads & abductor stretch
6	4:43	Core–Abdominals	Toe tap, twisting bicycles, plank
7	4:38	Core – Back	Plank, half camel, half crocodile, bow pose
8	4:10	Twists	Spinal & kneeling lunge twists
9	5:24	Forward Bends	Half cow, tabletop pose
10	5:34	Relaxation	Breathing, relaxation
11	4:26	Meditation	Deeper relaxation

The BodyBalance choreography (see appendix xxxvii) consisted of 11 tracks ranging from the warm-up, which took 3 minutes 46 seconds, to the hip-openers that

lasted for 6 minutes 9 seconds. In the event a participant missed a session, they were asked to attend a replacement BodyBalance class, the cost of which was recompensed by the researcher. This could be at the leisure centre most accessible to their home or one close to the University campus where the same three instructors taught. In principle, the choreography in use throughout all leisure centres would have been identical to that used for the study 3. The provision of the above options assisted participants to complete the required 30 sessions prior to the post-testing sessions.

Control Group

Participants in the control group were asked to attend two 90-minute workshops on back pain run by a physiotherapist employed at the University. One workshop was held in week 2 and a further workshop on week 6 of the intervention period. Both took place over lunchtime from 12:30 to 14:00 in a conference room on campus. Lunch was included to encourage a social environment and promote the benefits of group stimulation (Desharnaise *et al.*, 1993). The first workshop (see appendix xxxviii) looked at the prevalence of back pain, anatomy of the spine, normal range of movement, causes of back pain, injury, posture, prevention and management. The second workshop (see appendix xxxix) dealt more in depth with possible causes and gave practical exercises and advice on coping or improving symptoms. Participants were verbally discouraged from practising the techniques until after the post-testing sessions. Workshop information was structured in such a way as to dissuade this.

Interviews

The interpretive paradigm sets out to make sense of the “social” world we inhabit from an individual’s own subjective bank of experiences (Sparks, 1992; p26). It encompasses all forms of qualitative research, including case studies and the philosophy behind phenomenology. Smith, Flowers and Larkin (2009) explains how one form, Interpretative Phenomenological Analysis (IPA), helps to explore the significance of “lived experiences” in a person’s life. They suggest that the researcher acts as the tool who helps participants to consider and reveal those experiences, and then interprets, analyses and presents these multiple experiences in a manner that promotes and provides theoretical understanding. Like most interpretive research, it will also convey a variety of different meanings according to the personal experiences of the person reading it. Due to the ability of IPA to help understand back pain from the participant point of view, it is an acceptable vehicle for assessing and reporting interview data.

Interviews were conducted immediately before both testing sessions in a small meeting room near the laboratory. Participants were advised each interview would be recorded and that information derived from it could be published, although identities would remain anonymous. They were informed of their right not to answer questions and to have the Dictaphone switched off at any point. The interviews were of a retrospective, semi-structured nature (Smith, Jarman and Osbourne, 1999). Consisting of open-ended questions (see appendix XL) this format ensured a constructive, focused direction to the meeting whilst allowing the flexibility for either party to develop the discussion on points of relevance. Recordings were transcribed verbatim and then analysed using IPA (Smith,

et al., 2009), emphasizing the experience of living with back pain from the individual's perspective. It was hoped that this mixed-method approach to analysis would enhance the richness and complexity of back pain data by addressing issues not fully covered by quantitative methods alone (Green, Caracelli and Graham, 1989).

The main areas outlined for further consideration at the first interview revolved around back pain and its toll on everyday living including areas such as exercise. The second interview reviewed whether changes had occurred, in light of the intervention process; along with questioning the status of statements made by the participant during interview one. It also discussed whether individuals felt their original goals, or reasons for participating in the study, had been achieved. One particular individual seemed to stand out in the initial interview, both through the physicality of her posture as well as by the extent to which back pain had influenced her life. It was felt that the unique context of her interview would be lost through IPA's thematic consideration and representation of the group data. The decision was therefore made to relay the information as a case study. The background to this participant has been given below although the results from the initial testing session, including items that differentiated her from the others, have been covered within "results".

Case Study

Sarah (a pseudonym), 37, had seen a physiotherapist for her back pain and was currently having hydrotherapy as the physiotherapist involved was unable to treat her due to the level of discomfort caused by a tactile approach. In addition, she was asked to gain

participation approval from the same physiotherapist, as she was familiar with any relevant medical history.

The HLQ gave Sarah's vocation as a student, not currently exercising, who had attended weekly yoga classes approximately six years earlier for the duration of one year. With respect to low-back pain, she suffered the initial attack after her second pregnancy, which was four years before applying for the BodyBalance study. Her pain was bearable, although sometimes acute, lasting from a few hours to a day. She estimated between twenty to forty occurrences since onset, with the latest incident a week before completing the HLQ. The last section of this questionnaire used a Likert-type scale from 0 to 5, representing "not at all" to "extremely", to rate five questions regarding participants perception of the pain they currently experienced. Sarah assessed her current pain as "4" in terms of how "bothersome" she felt it had generally been throughout the week and a "3" in respect of how specific events resulting from having pain had interfered with her normal working day. She also indicated that over the preceding 4 weeks, she had reduced her "daily activity" for more than ½ a day on six separate occasions as a consequence of the pain. These primarily necessitated a reduction in housework, studying and chores related to the children.

Statistical analysis

Quantitative data established at both the baseline and post-intervention testing sessions were analysed on SPSS (version 15.0) software and expressed as mean and standard deviation. Mean values were calculated from data entered into a table format for

each variable within the BodyBalance and control groups. All data were checked for normality using Shapiro-Wilk prior to running any further tests. Independent t-tests were used to establish significant differences between the groups at baseline. Providing data was normally distributed, a 2 x 2 ANOVA calculated differences between the groups and any resulting group by time interactions. With non-normal distributions displaying an extreme outlier, the first course of action was to remove the item to determine the effect on normality. Non-parametric tests were then used to analyse all other non-normally distributed data as well as that from the Psychological Questionnaires. Qualitative data provided from the interview sessions were transcribed according to procedures from interpretive phenomenological analysis (Smith *et al.*, 1999). Initial readings of the text led to the identification of “meaning units” that were loosely labelled as first order themes according to the interviewer’s interpretation. Next, similar first order themes were clustered together into second order themes, which highlighted and were associated with those psychological dimensions that captured the essence of the participant’s perspective. This encouraged both meaning and a variety of themes, which were not restricted by the confines of any predetermined structure, to be extracted from the transcript.

6.4 RESULTS

The BodyBalance group and the Control group did not differ significantly at baseline for any anthropometric, physiological, biomechanical and psychological measures. The data for variables weight, BMI, eyes-open Romberg test, eyes-closed Romberg test, dynamic balance, sit-up test, sit-and-reach test, flexibility

measures and back strength were normally distributed. Significant differences in normality however were noted for the Sørensen test, the dynamic trunk extensor endurance, the McGill lateral test and the McGill flexor test. All of these variables included one extreme outlier and once this was excluded, the three latter variables displayed a normal distribution. The Sørensen test along with the ordinal data of the QDS and OLBQ, which also showed non-normality, was analysed using Mann-Whitney.

Table 20. Anthropometric measures study 3 (mean \pm s.d.)

Parameter	Control group (n = 7)		Body Balance group (n = 7)		P value ^a
	Baseline	Post treatment	Baseline	Post treatment	
Body Mass (kg)	67.8 \pm 13.4	69.3 \pm 14.1	64.5 \pm 9.4	64.5 \pm 9.4	0.217
BMI	24.7 \pm 4.0	25.1 \pm 4.0	23.0 \pm 3.0	23.3 \pm 3.6	0.750

^a time*group interaction; BMI, Body mass index;

Comparisons of anthropometric data are shown in Table 20. Baseline measures for body mass & BMI indicated no significant differences existed at outset between the BodyBalance and control group. In addition, there was no significant interaction over time.

Table 21. Balance, flexibility & strength measures (mean \pm s.d.)

Parameter	Control group (n = 7)		Body Balance group (n = 7)		P value ^a
	Baseline	Post treatment	Baseline	Post treatment	
Romberg- EO (mm)	564.1 \pm 136.6	571.8 \pm 154.4	696.7 \pm 232.9	561.3 \pm 126.8	0.049*
Romberg- EC (mm)	1089.9 \pm 376.6	1183.4 \pm 265.7	1484.3 \pm 728.7	1351.8 \pm 623.7	0.143
Dynamic (s)	19.2 \pm 3.7	22.2 \pm 2.5	19.5 \pm 5.3	23.2 \pm 6.3	0.624
Sit and reach (cm)	33.7 \pm 9.0	34.5 \pm 10.7	38.3 \pm 5.5	42.2 \pm 2.9	0.318
Hip flexion ($^{\circ}$)	117.8 \pm 11.7	116.1 \pm 10.1	111.9 \pm 9.4	117.2 \pm 6.3	0.023*
Hip extension ($^{\circ}$)	10.52 \pm 2.6	11.7 \pm 2.5	15.1 \pm 5.4	17.1 \pm 6.4	0.650
Hip abduction ($^{\circ}$)	17.5 \pm 3.7	15.6 \pm 1.9	20.0 \pm 2.3	23.8 \pm 3.3	0.003**
Lateral flexion ($^{\circ}$)	61.4 \pm 7.6	58.4 \pm 9.3	58.0 \pm 12.6	65.3 \pm 6.8	0.016*
Back strength (kgf)	46.6 \pm 12.7	58.1 \pm 30.7	41.4 \pm 10.9	63.4 \pm 22.9	0.337

^a time*group interaction; EO, Eyes open; EC, Eyes closed; * $P < 0.05$; ** $P < 0.01$

No significant differences were displayed at the preliminary testing session for any of the physiological or biomechanical parameters. For balance measures (see Table 21) “repeated measures ANOVA” indicated a significant effect of BodyBalance on the Romberg single-leg stance with eyes-open ($F_{(1,12)} = 4.81$; $P < 0.05$). This showed a reduction for the experimental group on the COF travelled way, recorded on the RSscan pressure plate, from 696.7 \pm 232.9mm to 561.3 \pm 126.8mm. The control group, however, increased the distance travelled marginally from 564.1 \pm 136.6 to 571.8 \pm 154.4mm. The same test with eyes-closed and the dynamic balance test on the stabilometer did not

indicate any significant effects of the exercise programme. The flexibility measures are somewhat interesting in that the sit-and-reach test, which involves an element of hip flexion, was not seen to be influenced by BodyBalance but the ROM measure for hip flexion was ($F_{(1,12)} = 6.85$; $P < 0.05$). The change in flexion reduced slightly for the control group from $117.8 \pm 11.7^\circ$ to $116.1 \pm 10.1^\circ$ whereas the BodyBalance group increased from $111.9 \pm 9.4^\circ$ to $117.2 \pm 6.3^\circ$. With the exception of hip extension, all remaining flexibility measures showed a significant interaction with hip abduction ($F_{(1,12)} = 13.18$; $P < 0.01$) and lateral flexion ($F_{(1,12)} = 7.83$; $P < 0.05$) increasing for the exercise group by $3.8 \pm 1.5^\circ$ and $7.3 \pm 9.6^\circ$ respectively.

Table 22. Trunk endurance measure (mean \pm s.d.)

Parameter	Control group (n = 7)		Body Balance group (n = 7)		P value
	Baseline	Post treatment	Baseline	Post treatment	
Sit ups (s)	66.8 \pm 28.4	57.5 \pm 44.4	50.1 \pm 33.7	97.8 \pm 39.0	0.004 ^{a**}
Dynamic extensor	17.2 \pm 1.7 ^b	16.8 \pm 6.3 ^b	13.3 \pm 7.3	22.6 \pm 4.2	0.024 ^{a*}
McGill lateral (s)	28.9 \pm 19.6	27.1 \pm 23.6	17.3 \pm 10.0 ^b	27.9 \pm 8.0 ^b	0.035 ^{a*}
McGill flexor (s)	55.4 \pm 35.3	41.7 \pm 30.3	36.7 \pm 25.3 ^b	48.0 \pm 15.7 ^b	0.066 ^a
Sørensen test (s)	131.9 \pm 67.4	107.6 \pm 63.8	116.5 \pm 84.1	143.8 \pm 61.1	0.055

^a time*group interaction; ^b n = 6 participants; * $P < 0.05$; ** $P < 0.01$.

The outcome of the trunk endurance measures (Table 22) was varied. Highly significant group over time interactions ($F_{(1,12)} = 12.61$; $P < 0.01$) were displayed for the

sit-up test with the duration of sustained curl-ups increasing by approximately 95% from 50.1 ± 33.7 to 97.8 ± 39.0 seconds. Likewise, the 60-second dynamic back extensor and McGill lateral musculature tests ($F_{(1,11)} = 6.87; P < 0.05$ and $F_{(1,11)} = 5.79; P < 0.05$) increased significantly from 13.3 ± 7.3 to 22.6 ± 4.2 repetitions and 17.3 ± 10.0 to 27.9 ± 8.0 seconds. This indicates an increase of 70% and 61% respectively. No significant differences were established for the McGill flexor endurance test or the Sørensen test although in both cases the mean for the control group diminished from preliminary to post-testing whilst the mean for the exercise group increased.

Table 23. Psychological measures (mean \pm s.d.)

Parameter	Control group (n = 7)		Body Balance group (n = 7)		P value
	Baseline	Post treatment	Baseline	Post treatment	
QDS	11.7 ± 9.1	20.3 ± 13.4	30.7 ± 20.7	11.9 ± 12.9	0.003**
OLBDQ	9.1 ± 5.6	11.0 ± 5.4	11.1 ± 9.1	6.1 ± 7.1	0.040*

QDS, Quebec back pain disability questionnaire; OLBDQ, Oswestry low back pain disability questionnaire; * $P < 0.05$; ** $P < 0.01$.

At baseline an independent t-test displayed no significant difference between the groups for either questionnaire (Table 23), despite what appeared to be a rather large difference for the QDS ($t = -2.23$; $df = 12$; $p = 0.056$). With the use of Mann-Whitney there became apparent a highly significant difference for the QDS with the BodyBalance group, reducing the level of pain assessed by approximately 61% from 30.7 ± 20.7 to 11.9 ± 12.9 . Similarly, the OLBDQ showed a significant reduction of 45% from $11.1 \pm$

9.1 to 6.1 ± 7.1 . Both questionnaires did however, register increases in back pain disability for the control group.

No distinctions were made at the preliminary interview stage between the BodyBalance and control groups, as participants fulfilled the same criteria and were randomly assigned. Again, pseudonyms have been used in place of interviewees (Table 24).

Table 24. List of Interviewees (pseudonyms)

CONTROL GROUP	BODYBALANCE GROUP
Lydia	Sarah
Michelle	Lucinda
Diane	Susan
	Rachel

Data analysis of the preliminary interviews (Table 25) yielded a number of first order themes that were subsequently clustered into five major second order themes: experience of back pain, understanding the pain, coping strategies, questioning own identity and motivation to exercise. Each second order theme was then reviewed in turn, as is typical in IPA studies, with first order quotes used to support the interpretation and categorisation made.

Table 25. Analysis of Preliminary Interview Data

First Order Themes	Second Order Themes
<ul style="list-style-type: none"> • Dull chronic ache vs. intense, sharp pain • Pain intermittent to continuous • Pain daily to occasionally • Unbearable or bearable • Gradual onset vs. immediate onset • Specific vs. general localisation of pain • Discomfort, soreness, stiffness, rigidity • “Snapped elastic band” sensation • Fatigue, difficulty sleeping • Lack of concentration • Tension, nervousness, stress, frustration 	Experience of back pain
<ul style="list-style-type: none"> • Knowledge of original cause • Extent of self-knowledge • Factors influencing intensity of pain • Knowledge of & ability to act on “triggers” • Fear of pain • Fear of immobility, seizures & spasms 	Understanding the pain
<ul style="list-style-type: none"> • Adjust position for pain relief • Cautious movement transitions • Control range & type of movement • Self-imposed restriction of activities • Limit impulsive reactions • Reduce /increase activity level • Self-efficacy of exercise • Heat/cold, therapy, massage, medication • Extending pain thresholds • Sleep & rest • Adjustment of equipment & furniture 	Coping Strategies
<ul style="list-style-type: none"> • Uncertainty of the future • Freedom to choose activities • Reliance on others • Mood disturbances & depression • Social withdrawal from others • Feeling that others “don’t get it” • A sense of normality • Managing the reaction of others 	Questioning own identity

- Desire to exercise
- Exercise rarely vs. regularly
- Motivated by “fun” or others
- Group exercise classes/ individual formats
- Limited capacity for 100% physical input
- Actual-ideal discrepancy in exercise goals
- Impact of exercise on posture and alignment
- Connection - posture, back pain & exercise

Motivation to exercise

i. Experience of back pain

This theme looked at the general parameters of pain experienced by the individual along with related psychological responses and behaviours. The descriptions given by all interviewees varied greatly as to what each perceived to be a physical manifestation of the “invisibility of chronic pain” (Morley; 2008; p29). Rising from the dull constant ache felt at some point by five of the interviewees, the sensation developed into a state of acute pain for two of this group, although another described it as just “intense”. Two of the group also suffered from muscular seizures extreme enough to leave them immobile and unable to “get up” or move. Sarah, the case study participant and a mother of three young children, described her experience as “it used to seize up a lot...the worse was overnight, my husband didn’t know whether to get an ambulance because I was completely stuck... sometimes it gets really unbearable”. Lydia, a slightly older participant, explained her initial occurrence; “It’s just like an elastic band had snapped... I was sort of doubled over completely... it took several hours...”. The ability to function normally also becomes affected by the limited capacity to complete certain tasks. For example, Lydia explains, “You can’t move in certain ways, you can’t do certain things” and Lucinda supports this with, “I would like to do things which I cannot do”. At times, the restrictions become severe enough that they create a need to rely on

others to complete a task, taking away the feeling of independence and self-efficacy. Sarah shared an example of how it affected her family life, highlighting the necessity for her husband to accompany her on family outings. She said "...we go to outdoor play areas. Before I would have been able to climb everything with them, my husband does it now... 'cos there's a fear of me seizing up". Although seizures happened at home she felt more vulnerable when outside with the children. Finally, the physical distractions created by pain serve to interrupt a participant's daily life with constant reminders of condition-imposed limitations resulting in displays of behaviour such as frustration, stress, lack of concentration and sleep disorders. Lucinda stated, "I lose the concentration because of the pain" when discussing the attendance of lectures at college. However, unlike others in the group, she found the pain "disappeared" when she lay down to sleep. For most participants it would hinder and interfere with their sleep pattern. The views of five others were "...the worst time would be trying to sleep at night... I was uncomfortable", "...if I move in the wrong position, it wakes me up", "I can't fall to sleep easily... it really hurts...it shortens my sleep pattern, I am not getting the sleep" and "...the lower back did wake me in the night... I must have been turning".

ii. Understanding the pain

Generally, there is a requirement for an individual to understand and make sense of any pain they experience (Eccleston, 2001). In the case of back pain, this is somewhat difficult to accomplish as in many cases there is no known aetiology. In this instance, however, out of the seven interviewees only two remained uncertain of the original incident that brought about their condition. Most were able to identify the onset, stating

examples that included accidents, pregnancy or incorrect lifting techniques. In addition, they felt the more they were able to identify events that would trigger an attack, the more they would be able to stop an occurrence or at least reduce the severity. This was explained quite well by Michelle who suggested that her symptoms would become worse if she was “not listening to the first effects, not pulling back and carrying on”. A variety of such triggers disclosed for all the interviewees included illnesses, walking, poor lifting technique, car journeys, sitting, tension, “cold” weather, soft mattresses and menstruation.

A further area of interest related to the understanding of back pain was the impact of “fear”, or more specifically the fear of pain, immobility and spasms. Affecting each individual within the group to varying degrees, this first order theme emerges from the ideas presented by the “fear avoidance model” (Vlaeyen *et al.*, 2000). This is where pain, if interpreted as a signal of impending injury or danger, would result in the avoidance of such activities. Continual avoidance of such activities would in turn lead to disuse and acquired disability. Sarah expressed this as “I’m afraid to get stuck. I’m so afraid of getting as bad as when it really seizes up that I avoid doing things”. She also linked it to how she coped with pain in that “... I think the fear of getting the pain actually stops you trying to do things, because you are just trying to manage it all the time”.

iii. Coping Strategies

Eccleston (2001; p147)) refers to one definition of “coping” as the “response to a stressful event”. This would suggest that faced with any type of stressful situation, including pain or the fear of pain, there is a positive or negative response that will vary in intensity. Strategies to “cope” with back pain are either built upon the relationship between the individual and the environment, resolved by looking at the different solutions to the problem or controlled by regulating the emotional stress created by the experience. A number of first order themes were highlighted from the transcripts that relate to such solutions. One of the most identifiable was the use of pain medication, massage, heat/cold applications, and therapy including physiotherapy, chiropractors and osteopathy. What seemed interesting was that, despite three interviewees listing painkillers, most did not like to and one, Susan, even stated, “I don’t want to be addicted”. A further concept revolved around the fear of pain created by the necessity to move and its associated management. Interviewees expressed an air of caution in the way movements were executed when conducted under the influence of back pain. Lydia’s views reflect this when she said “ I’m very conscious of the way I do things when I’ve got back pain...how I get into the car, how I get out of bed, put something in the bin, put tights on... have to be careful”. Likewise, Sarah commented “...you have to think about everything you do before you do it as opposed to just doing it” and Michelle clarified “...for me it’s limitations, constantly assessing situations, working out how to go about things”.

Exercise can be regarded as a means of coping with stress (Madden, 1995) due to its stress reducing qualities and the ability to enhance the components of physical fitness. This is substantiated in these interviews by Lydia who felt that “I think exercise is good for us... endorphins make you feel better...it makes me feel completely better. I don’t feel as if my back is weak ...I don’t feel I have to be conscious of it”. The type of exercise preferred by the group seemed to be of a low-impact nature with “swimming” being seen as a popular choice. For example, Susan said “Swimming actually helps if I have back pain”, whilst Lydia felt “there have been times in my life when my back has been excellent, usually when I’ve been swimming” and Lucinda stated “...the pain is decreased after that [exercise] because I go to the gym and I do the swimming and then afterwards I feel better”. Alongside exercise, relaxation in varying forms could help minimise stress and its elicited responses. One of these responses is tension and according to Lydia, “I feel my whole body stiffens...I can go quite rigid in my body...any sort of tension that I hold in my body seems to affect it [back pain]”. The underlying suggestion is that inducing a state of relaxation, which is the opposing state to tension, generates a positive impact upon back pain.

iv. Questioning own identity

The unpredictability, limitations and nature of chronic pain creates confusion and uncertainty from the perspective of the sufferer that influences their sense of identity. Firstly, back pain appears to create feelings of isolation for interviewees in a number of different ways. One is that it is not an injury obvious to other people, as there are no physical signs to validate the pain they experience, despite the fact that it may be quite

severe. For this reason, sufferers often withdraw away from their social network rather than feel that they have to justify their behaviour. According to Lucinda, “They prefer to stay at home and stay maybe on their own as well”. From a personal angle she said, “I don’t feel like socialising with people. I socialise on the internet with people, you don’t have to explain your situation. I prefer to stay home safe”. Next, there was a sense that sufferers were not being understood. Again, Lucinda expressed her frustration by saying “Now I don’t like to explain that I can’t really do things because of the back pain...I choose just a few people who understand, the close people I want to have around”.

Michelle also felt frustrated at the fact that “People see me and they don’t get any of this.... they assume I’m upright and mobile, all ok”. She then goes on to explain how she chooses to maintain a sense of normality by avoiding the demonstration of pain behaviour “...there’s a lot that goes in to make it look ok...it’s quite a little show going around”. A similar desire to maintain normality was expressed by Susan who stated “How would you ask a lecturer to stand up and walk around...I was suffering you know rather than ask”. Finally, there is the issue of dealing with people’s reactions. According to Michelle, “...can manage my stuff instead of someone else’s reaction as to why I can’t do something. Don’t get it when they invite me, I say no, they find that hard to understand”. Finally, the inability to cope with and deal with the disability in a positive manner can sometimes lead to a sense of despondency and depression. Lucinda, a Masters student, appeared to have been the member of the group most affected by depression and talks about it as if she expected all back pain sufferers to experience the same. She expresses the influence on her life, as “I feel depressed, the back and the pain...I had to stop the school (Lucinda had to withdraw from her University course) and

so it makes me feel depressed, sometimes sad...it makes you tired and depressed and giving up sometimes...” These feelings, commonly associated with depression, are related more to the disabling consequences of the chronic condition rather than the severity of the pain itself. Lucinda expands on this with “I would like to do things which I cannot do...don’t feel like going to school...don’t really feel like going on holiday... I felt like my life was not going because of the back pain”.

v. Motivation to exercise

Out of the seven interviewees five were actively performing some type of regular physical activity and two, one from each of the groups, were unable to exercise. All seemed to believe the relationship between posture, back pain and exercise existed, hypothesising that regular exercise would improve postural alignment, which in turn reduced back pain. According to Lydia, “There have been times in my life when my back has been excellent, usually when I’ve been ... a bit more active”. Similarly, Lucinda said, “Just very slowly I swim ...because it makes my back better”. Despite the desire to minimise back pain, there seemed to be a lack of intrinsic motivation to maintain the activity. One interviewee, Diane, had remarked on the use of “Wii fit”, “I probably used it every day in the last two weeks, but its fun”. For all others, however, the motivation to exercise was not strong enough to overcome the degree of pain encountered as a result and the limitations imposed by time. One example of the former is Lucinda discussing the quantity of exercise undertaken with “I used to be able to swim fifty lengths, now it’s ten...because afterwards it brings the pain”. Concerning time constraints, remarks such as Sarah with “It’s trying to fit it in [swimming] with three

kids” and Lydia with “as you get older you need to do more...but because of life’s pressures...” were common.

Table 26. Analysis of Post-Intervention Interview Data

First Order Themes	Second Order Themes
<ul style="list-style-type: none"> • Back pain is better or worse • Changes in frequency or symptoms • Change of “triggers” • Influence on sleep 	Experience of pain
<ul style="list-style-type: none"> • Postural alignment & its impact on pain • Extent of self-knowledge • Relevance of workshop • Application of workshop information • Feelings of progression in BodyBalance • Group experience 	Understanding the pain
<ul style="list-style-type: none"> • Avoid/plan for tasks that trigger pain • Vary daily routine if signals predict pain • Adjust position for relief • Therapy treatments, medication 	Coping Strategies
<ul style="list-style-type: none"> • Reliance on others • Social withdrawal from others • Depression 	Questioning own identity
<ul style="list-style-type: none"> • Desire to exercise • Stages of change • Change variables of exercise • Extrinsic motivation, “go with the girls” • Intrinsic, “I really did try” & enjoyment • Connection- posture, back pain & exercise 	Motivation to exercise
<ul style="list-style-type: none"> • Control & prevent recurrences of pain • Reduction of pain & risk of back injury • Improvement in postural alignment & strength • Information & understanding of back pain • Becoming more active • Self-efficacy & self confidence • Improvement in “quality of life” 	Achievement of goals

Data analysis of the post-intervention interviews (see Table 26) maintained some of the first order themes displayed at commencement of the study, although the emerging categories resulted in one additional second order theme labelled “achievement of goals”. It considered the development of themes, looking for differences between the groups that arose because of the intervention process. In most cases, the views of the two groups were expressed separately due to the different experiences encountered.

i) Experience of pain

The preliminary interview noted all of the seven interviewees were experiencing symptoms of back pain. Post intervention, an interesting division appeared between the respective groups in terms of how the pain had evolved and whether it felt better or worse than at the start of the study. Firstly, all four participants of the exercise group felt that their back pain had improved. Rachel, Susan and Sarah commented as follows: “The pain has completely gone, it’s not there anymore”, “I have no pain for at least two weeks now” and “virtually nonexistent ... the pain itself seems to have gone.” Rachel and Susan noted this effect around week four or five, halfway through the intervention programme. The final participant of the exercise group, Lucinda, said “It’s still painful...maybe it’s better... I feel like I am stronger ...maybe it’s not so severe”, suggesting some positive change had occurred. Secondly, out of the three participants from the control group two felt the level of back pain had remained the same whilst one felt it had deteriorated. Lydia still felt vulnerable, as she had “...hit one of the episodes”, Michelle was “tentative” as she was uncertain “...what’ll set it off” and Diane had to visit her doctor as she felt her back had “locked” with the pain described as severe as

“when it first started”. A further aspect of experiencing daily pain was the impact on sleep and resulting conditions from lack of sleep. At the initial interview three out of the four BodyBalance interviewees suggested that the pain either interfered with them getting to sleep or woke them up when they changed position. They now clearly stated that it no longer kept them from going to sleep or woke them up once asleep. The situation with the control group, however, remained the same. Overall, the differences to the BodyBalance group meant fewer interruptions to their daily routine as a result, leaving them more able to accomplish simple tasks without encountering pain or worrying about initiating another episode. Sarah was now able to “...bend down, get back up... [put] kids to bed... [put] them in the bath and drive”. Susan sat for seven hours in front of a computer then realised she had experienced “no pain” as a result once she went home. She commented, “It’s easier to realise when you are in pain than when you go back to normal”.

ii) Understanding the pain

The need of an individual to identify and understand the pain being experienced was outlined during analyses of the first interviews. The method by which they accomplished this, however, differed for each of the two groups. The exercise group engaged in BodyBalance training, which induced physical changes in terms of balance, posture, flexibility, strength and endurance, ultimately resulting in a change in psychological behaviour. The control group was given verbal information from a physiotherapist about the causes of back pain and what could be done to help alleviate symptoms. Within the BodyBalance group, the understanding developed over time with

repetitive practice of movements that allowed individuals to experience the changes or sensations that were taking place. Rachel commented on how “You really have to concentrate and focus, you get to feel where the stretch, pain or tension is...you understand where your back pain is coming from”. In a similar manner Sarah stated “...repetition all the time, reminding you of what you should be doing, what you should be feeling”. She also expressed the difference the reduced interruptions of acute pain and associated fear of pain had made to her freedom of choice. She said, “Before, everything was centred around pain and how much it would give me...now, because I’m freed up from the pain, I think a bit more logically about doing things”. Lucinda also shared how she gradually overcame the limitations imposed through fear, explaining “In the beginning, I was kind of afraid and in the end I was doing all the exercises”. A strong theme underlying the control group seemed to be the reassurance they gained from workshops to make them feel they were not suffering alone, that others could relate to the difficulties they were going through. Examples of this include Diane who stated “...other people’s views on back pain...didn’t realise it was different for other people” and Lydia added, “...seeing other people and hearing what they’ve got to say about their problems”.

iii) Coping Strategies

Upon commencement of the study, participants identified different treatments, movement control, exercise and relaxation as methods of reducing the intensity of pain. A prime consideration within “treatments” was medication, although most interviewees had stated a preference not to use it where possible. Variations to these parameters were

noted for two individuals within the BodyBalance group, namely Rachel who had used ibuprofen gel but no longer needed “to use it on [her] lower back” and Sarah who felt she now only suffered from muscle soreness as the pain “...sorts itself out by the next day”. Next, came strategies to influence movement, starting with Sarah and Susan from the BodyBalance group who both indicating their back pain had virtually disappeared and as such were taking measures to maintain this status. Sarah was aware of how to lift correctly mentioning “I lift in a different way now...bend my knees” and believed if her posture went back “to the way it was...then back pain could come back”. Susan reinforced this by saying she was “more aware of posture... otherwise it becomes painful again”. Lucinda had even declined the offer of a job so she would not be resigned to “...sitting down” thereby aggravating her existing condition. She, like Lydia, Michelle and Diane in the control group, adapted her physicality to prevent another attack. Lydia was conscious that her back was sore and as such said “I have to be careful...everything I do is planned...if I push myself too far I could not be walking tomorrow”. If she did not adapt when she “hit an episode” she felt a period of ten to fourteen days could turn into a month of being “on the floor” unable to walk and a further three weeks before “being able to function”, so a fear existed of prolonging or increasing the intensity of pain. She admitted trying to apply preventative advice gleaned from the physiotherapy workshop saying, “I am conscious of the problem... I’ve definitely thought about it”. Michelle had also “adjusted her behaviour” following advice from the workshop but was still coming across many obstacles. Her life depended largely on others and one such example of this was working on her allotment. She felt “...like there is a limit... have to enlist people to be with me...rotate people... needs availability and people to do it”. The other was

travelling by bus because “On a good day the maximum is forty minutes...debate whether I can get upstairs...takes a while to get up from my seat to get off”. Finally, Diane chose to rely on her father to “...drive down to London and then drive her back up to Birmingham” rather than travel to Birmingham by train carrying her bags in case this increased the pain.

Moving onto exercise as a means of coping, two participants from the intervention group had differing outcomes. The BodyBalance sessions had made Rachel feel “a lot better...fitter...stronger”, releasing her from some of the inhibitions associated with pain. Lucinda, however, found it restricted her as exercise was her management tool and the thought of going on a holiday left her feeling afraid she would “lose this routine” resulting in increased pain. The “routine” in this instance referred to the simple exercises from the physiotherapist she did three times each day. Additionally, included within the structure of BodyBalance was relaxation and both Rachel and Lucinda remarked how much they enjoyed this element. Ultimately, this would have an impact on intrinsic motivation and maintenance of the activity.

iv) Questioning own identity

It was suggested that back pain imposed a restriction on the ability to choose and that over time it could cause sufferers to withdraw from social groups. In doing so, they could avoid having to explain their feelings or alternately they could “put up” with the pain in order to preserve an air of normality. This in turn had an impact upon their identity. A change in the need to withdraw from social networks was most apparent with

Lucinda who, at the start of the study, showed signs of depression and was harbouring a bleak outlook. Although still feeling "...depressed and sad" she said post intervention that she was "...trying to escape" and that it was "...probably better for the body to heal if one is positive". She had started to socialise again by "...going out... to meet people" with "some kind of direction" and was "...more positive".

v) Motivation to exercise

The belief of all interviewees at the start of the programme was that exercise would have a positive effect on back pain. However, the motivation to actually exercise, rather than just contemplate taking action, needs to be strong enough to overcome the fear of subsequent pain and associated disability. Taking part in BodyBalance, Rachel's intrinsic motivation was derived from the social dimension of being part of a group along with praise given to her by her mother about her posture. Physically she noticed the difference in her core region stating, "Stomach's got a lot, lot stronger... sit-ups from the first week to the last week, it's just pretty amazing". Sarah was optimistic about progress and noticed the way it "made life a lot better not carrying pain around". Lucinda again was encouraged by participation and subsequent progress saying, "I did [enjoy the classes], they were very nice....made me realise I can do more than I think". Both Lydia and Michelle from the control group announced they enjoyed the physiotherapy workshops but did not seem to follow this up with much conviction during the interviews. Lydia commented with "yeah, they were good" whilst Michelle stated "yeah, I did....I was pleasantly surprised. I liked the explanations... quite informative". Diane, the last of the control group, showed signs of relapse explaining, "I started half an hour

every day, that was like the first couple of weeks....but one day will go by and before you know it a whole week has gone by and I haven't touched it". Finally, when interviewees were asked whether they would recommend BodyBalance as a way of improving back pain all seven agreed that they would. As Sarah put it "...lessening the pain without taking a pain killer" or Michelle "look at it like taking medicine".

vi) Achievement of goals

The "achievement of goals" is an additional post-intervention second-order theme included to assess whether individuals felt they had achieved the goals they had set for themselves at the outset of the study. At the preliminary interview, interviewees were asked what they would like to achieve following study participation. In most instances, individuals identified fairly short-term, realistic goals in terms of time and objective. Now post-intervention, starting with the exercise group, Rachel was pleased she had managed such "...a big commitment [three BodyBalance sessions per week]". Regarding the class as a whole she praised them by explaining that "...at the beginning [they] were a group of back pain people, by the end of it a normal class". Feeling fitter in herself and "better aligned", she set her sights on running a 10k race in eight weeks time. Sarah could "exercise now", although progress had been difficult and changes gradual. She had "a lot more energy" and, following a conversation with her recent physiotherapist, had the idea she had "...gone back ten years". She understood this to be a positive change from the immobility and difficulty she was encountering before taking part in the BodyBalance treatment, to the health and vitality she experienced when she was ten years younger. She could "lay flat on [her] back now without it hurting" and

hold poses she never thought she would be able to do. To summarise she said “I felt so bad at the beginning, I didn’t think I’d feel so good at the end. I still thought I’d have a lot of back pain”. Susan aimed to continue with BodyBalance classes as she felt they were already in her “life”. She was now able to finish tasks, such as hoovering, that previously would have caused her considerable pain. She was also intending to go on a car journey through Europe with her friends, which would not have been an option at the start of the study because of the back pain. Her ideal at this stage was to “carry on life without pain”. Lucinda wanted to “build on” what had been gained from participating and maybe even teach BodyBalance or Pilates. She said she could feel the difference when seated as “the abs become stronger... feel more stability”. She believed that if she carried on getting “stronger ... the pain would ease up”. The control group interviewees remained in the contemplation and preparation stages of change (Prochaska and DiClemente, 1983). Lydia remarked “I know I should be doing it, I know that I’ll feel better if I do it...you plan to do it and something happens...it’s not good enough... hoping to go next week”. Michelle wanted “a set of exercises that fit in with the lifestyle” but “don’t quite know how to build up and do it”. Lastly, Diane had little intention of exercising and commented, “I’m just lazy, it’s just me”.

Case Study: Sarah

On entering the interview room for the first meeting, initial visual assessment indicated spinal mal-alignment, with Sarah’s head distorted to one side. Correct alignment of body segments, where they are all stacked vertically on top of each other, would have increased the efficacy of the musculoskeletal system. Her movement when

walking to the interview room was somewhat cautious and controlled, as is often the case with an individual wary that any sudden change might inflict pain. Her seated position for the duration of the interview was also in a distorted “S” shape, but upon being questioned she suggested this was the most comfortable position for her. The discussion that then followed helped give an insight into the impact back pain had had on Sarah’s life for the past three years.

Sarah had initially delayed seeing her GP due to the assumption this pain was a “normal” consequence of pregnancy. It was only when her back went into spasm at a doctor’s appointment for another matter, leaving her “stuck” in forward lumbar flexion, that she was referred to a physiotherapist. The physiotherapist, in turn, referred her for hydrotherapy as Sarah found it too painful to undergo any form of physical manipulation. In addition, she was advised to avoid lifting and breastfeeding. Her doctor informed her she suffered from pubic symphysis disorder, a dysfunction associated with the pelvic girdle, probably as a result of three successive pregnancies. She understood this might have been influenced by the prescription of “a lot of hormones”, to reduce the risk of premature labour, which caused her pelvis to “loosen up”. The pain continued after childbirth, possibly due to the hormonal effects brought about by breastfeeding. Despite having been a very active person who did “...a lot of exercise”, including 10 mile runs with the Territorial Army, weekly 2-hour martial arts sessions, yoga and gym work, Sarah’s life was now fairly restricted as she was “afraid to get stuck” or of “getting the pain back”. She was not someone who liked to be “...sitting indoors watching telly” as she preferred to “be walking around” so the pain also limited her freedom. In addition,

the mixture of the fear and discomfort she was feeling meant that daily tasks became hard to complete. She experienced difficulty "...doing the washing, bending down to take the washing out, lifting the kids up or out of the bath, shopping ... moving furniture around the house, going to outdoor play areas with her kids...[or] driving". Her basic desire was to "...be fairly straight" in terms of posture. She felt the hydrotherapy had helped get her to "straighten up" a little and by stopping breast feeding the spasms had "...got a little bit less". Should she achieve her goal through study participation, Sarah felt the level of back pain would improve enabling her to travel further in the car to see friends, exercise, take the dog out more, play with the kids and manage her housework better.

The preliminary testing session took place immediately after the interview and highlighted some interesting aspects. Sarah was able to balance for the Romberg test, but unlike most of the participants assessed for the study, she achieved her stability by leaning over to one side. She could not retain a balanced position whilst in vertical alignment. She produced the lowest score of all participants for the Sørensen, the 60-second back endurance, dynamic balance, hip flexion and hip extension tests. She was also the only participant unable to perform the sit-up test. This may have been partly due to the way her head tilted back, possibly signifying a weakness in the musculature surrounding the cervical vertebra as well as the lumbar. The score on the QDS was 51 (range 20 - 100), with the majority of everyday tasks regarded as "somewhat difficult" to "very difficult". The higher the score on this scale, the less the participant felt able to accomplish as a result of back pain. The OLBDQ score was 20, equating to a 40%

disability, which is moderate verging onto severe (moderate disability 21% - 40%; severe disability 41% - 60%).

Sarah has asked me to contact you regarding her treatment and management

She has agreed to me contacting you so I shall give a brief outline of her management. She originally presented with very poor posture, muscle spasm ++ and unable to stand properly, walk or manage any normal functional movements.

She was treated with Hydrotherapy to relax her muscles so that with some release we could achieve a good posture, improve back extension and then begin to start improving her core stability and shoulder posture.

She improved dramatically and worked hard to improve her posture in standing.


Just as I was considering putting her into our back programme she informed me of your body balance sessions and on questioning her about the exercises and frequency it seemed the perfect way for her to progress.

As you know she did very well, **Sarah** was very well motivated and when I saw her finally I considered she looked 10 years younger than when she first presented to me.

It is so important to continue exercises regularly and especially core and posture work. To be able to access and exercise regime easily and frequently is a brilliant idea and hopefully it can be continued and your model used by other agencies to promote better health and well-being within companies or groups of students.

Please do not hesitate to contact me should you wish to discuss this further. Thank you very much for your continued input with **Sarah** and others,

Regards,



Senior 1 Physiotherapist TMH,
Hydrotherapy, committee member for ATACP.

Fig. 6. Physiotherapist's comments (patient's name has been changed).

Sarah participated enthusiastically in the BodyBalance treatment. Over the duration of these sessions, a number of changes were observed in her ability to perform movements with the required ROM and technique. Two such examples were firstly,

when supine on the floor in anticipation of certain exercises or relaxation, the angle of her neck extension gradually decreased and, secondly, lumbar flexion increased from minimal forward bend to Sarah being able to reach her ankles. During that period, Sarah also went back to her physiotherapist who said that she would not have to return for further treatment. Towards the end of the intervention, Sarah requested an email from the senior physiotherapist involved (see Fig. 6), regarding the treatment and management of her condition, to be sent to the researcher. This provided a second opinion confirming the positive results achieved by Sarah following participation in the BodyBalance programme.

Sarah completed all thirty sessions and by the post-intervention interview seemed a much happier individual with improved posture. Her body segments produced what appeared to be a more comfortable alignment. Her neck allowed her head to look centred rather than looking as if it sat over the left shoulder. The kyphotic curve was less pronounced and she was able to sit in a more upright position without constantly readjusting herself or flinching in pain every time she moved. Initially her friends and family were concerned that participation in the study might make things worse, unlike the physiotherapist who "...thought it was brilliant" but now they commented on how much more relaxed she seemed. Sarah herself said that she looked "... in mirrors to see how straight" she had become rather than "hunched up" and felt rather proud of this achievement. With regards to the improvements within the BodyBalance class she particularly remarked on her "stomach" and said it was "... amazing that the muscles were still there...it's great because I didn't think I could get them working again after

having three kids in a row”. Likewise, in relation to the bow pose, she said “I can actually hold my feet; I never thought I’d be able to do that”. Concerning general improvements arising from participation Sarah mentioned a variety of areas. To her, the pain was “virtually non-existent now... [even seemed] to have gone”, which was a far cry from “...lot of lower back pain...constant ache...sometimes really unbearable”. The spasms she described as “...very, very, very painful...feels like something is gonna snap” were no longer part of her life so she was able to bend down, remain there and get back up without difficulty or fear of her back seizing up. This meant that if she sat on a beanbag to put the “kids” to sleep she would no longer get “stuck” and have to wait for someone to lift her up. In addition, the “fear of doing things” because of the resulting pain and the “having pain ...which is exhausting in itself” no longer had the same impact leaving her with more energy to cope with everyday tasks. She now actually enjoyed taking the dog for a walk. Furthermore, she was astounded she could “...actually lay flat ...without it hurting” rather than having to lie at an angle and it was comfortable to sleep like this rather than in a tight foetal position. This allowed her to sleep through the night without the pain waking her up. She could also sit comfortably in a car and drive for two hours to her friend’s house. Finally, she no longer suffered headaches and the numbness in her foot had gradually disappeared. Overall, Sarah summarised benefits by her comment “I think I’ve gone back ten years...its made life a lot better not carrying that pain around”. Alleviating the pain had made her aware of how much more she was able to accomplish. To attain her goal of becoming “fairly straight”, in terms of ideal posture, she felt approximately 75% of the way there. Likewise, the anticipated reduction in back pain had been surpassed as she no longer experienced any pain.

The results from the testing session that followed the interviews displayed some interesting changes, with the only variables showing no signs of improvement being the sit-and-reach test along with dynamic balance. The trunk endurance tests showed great improvements with the Sørensen hold-time increasing from 26.9s to 89.1s, dynamic extensor endurance from 2 to 23 repetitions and sit-ups from 0 to 104.7s. Similarly, the McGill's flexor endurance increased from 33.2s to 169.1s and McGill's lateral endurance from 23.6s to 31.4s. In terms of trunk strength and flexibility, strength improved from 47kgf to 100 kgf, hip flexion from 93° to 110°, hip extension from 6° to 10°, abduction from 17° to 20° and lateral flexion from 41° to 64°. Finally, the disability questionnaires displayed reduced impact of back pain on daily activity with QDS decreasing from a score of 51 to 9 and the OLBDQ from 20 to 0. This result of these questionnaires implied minimal disability now existed and indicated that Sarah could cope with most activities. No variables measured showed a negative change for this participant as a result of undertaking the workout programme.

To summarise: Sarah, by participating in ten weeks of BodyBalance, managed to bring about a number of positive changes in her life. She felt that she had become straighter and more independent. She no longer had to rely on her husband to avoid the consequences of muscle spasms and did not feel restricted because of the fear of pain. Her ability to participate with greater ease in providing for the needs of her children and herself had been enhanced, providing her with greater self-esteem and confidence. Physically Sarah was stronger, the much improved trunk strength, endurance, and flexibility would allow her a greater range of functional movement. Her general well-

being improved with the ability to get a full night's sleep, sit comfortably and walk without pain as well as exercise. Although this case study relates specifically to a single individual, it does support the argument that it is possible to enhance the life of someone with chronic back pain by taking part in exercise programmes such as BodyBalance.

6.5 DISCUSSION

BodyBalance, a recently developed but popular exercise programme available at leisure centres within the U.K and worldwide, has the same lack of “well designed” research supporting it that befalls most mind-body programmes. However, unlike yoga, Pilates and tai chi it has standardized choreography, making it an ideal intervention for use in investigations into a wide range of areas. The purpose of this study was to assess the longitudinal effects of BodyBalance on participants with back pain. Due to the subjective nature of pain, it was considered appropriate to use a combination of both quantitative and qualitative methods to provide a more balanced understanding of the effects of the programme.

The first topic of discussion concerns physiological and biomechanical measures, with special consideration given to their relationship in respect of relevant back pain research. To commence, this study showed no significant changes in both groups for body mass and consequently BMI. This is in keeping with previous studies involving adults undertaking Pilates and Feldenkrais workouts (Segal *et al.*, 2004; Sekendiz *et al.*, 2007; Gutman *et al.*, 1997). This outcome was anticipated, as BodyBalance is not specifically designed with the intention of providing a cardiovascular workout. The next

variable, “static balance”, produced a significant reduction on the “COF travelled-way” for the Romberg test in the eyes-open, single-leg stance ($P < 0.05$) suggesting an improvement. Dynamic balance, although the effect was not significant, showed an increase in “time in balance” implying that such balance had improved. In addition, the control group had also increased indicating possible learning effects. Study 2 of this thesis, compared static and dynamic balance using the same test battery, and concluded there was no difference in these measures between a back pain group and a healthy control group. In addition, the results of dynamic balance in the current investigation do not agree with an earlier study by Johnson *et al.* (2007) who used a functional reach test on an equally apportioned Pilates and control group to determine the change in balance following mind-body intervention. The reason for the inconsistency in the findings may well be attributed to the use of a stabilometer for the current study, which requires adjustment of lateral balance, in preference to the functional reach test that measures balance in a forward direction.

The results from tests relating to the components of fitness were unpredictable. In terms of flexibility, study 1 established a significant improvement in hip extension ($P < 0.05$), hip flexion ($P < 0.01$), hip abduction ($P < 0.05$), lateral flexion ($P < 0.05$) and the sit-and-reach test ($P < 0.05$) for a group of healthy participants participating in 12 weeks of BodyBalance training. However, the results of the current study produced a significant improvement only in hip abduction ($P < 0.01$), hip flexion and lateral flexion ($P < 0.05$), but not the sit-and-reach or hip extension tests for back pain participants. There is therefore the possibility of back pain status influencing the outcome of the

measure. The results of the sit-and-reach test were also a direct contradiction to Galantino *et al.* (2004) and Cowen (2010), for whom the effects of “hatha yoga” on 22 back pain participants or “yoga” on 108 healthy fire fighters respectively produced an improvement. Galantino tested the effects over six weeks and Cowen based her findings on an average participation of four classes as opposed to the 30-class requirement for the current study. The numbers of classes completed in this current study were therefore sufficient to produce a change in all measures of flexibility but they did so only for some. The difference therefore appears to revolve around group size and the distortion created by insufficient participants. Study 1 also established a highly significant improvement in back strength ($P < 0.01$) for healthy participants, again not in agreement with the current study. One interesting aspect of the current investigation, however, was the increase of back strength recorded for both BodyBalance and control groups. This was observed, despite the overall effect not being significant, thereby indicating a possible learning effect. This does not agree with the findings of Sekendiz *et al.* (2007), who tested the effects of five weeks of Pilates on a female group of whom eighty percent had experienced back pain and found a significant increase in back strength. Finally, accompanying strength were five measures of trunk endurance, which again had varying conclusions. The first of these, the sit-up bleep test, designed to measure abdominal endurance, proved highly significant ($P < 0.01$). To recap, “study 2” showed a significant difference existed between back pain sufferers and non-back pain individuals for this parameter, so there is an effect of back pain on this muscle group. It should also be mentioned that there were some questions in both studies regarding the suitability of this test for participants with back pain due to associated spinal loading conditions and

increased risk of injury (McGill, 2007; p8). This may account for one individual in study 3 unable to perform the required range of movements at the preliminary testing session. However, these findings support the research of Herrington *et al.* (2005), who tested the abdominals of healthy participants divided between abdominal, Pilates and control groups using a pressure biofeedback unit to assess performance of the Transversus abdominis during an abdominal hollowing exercise. They concluded better lumbo-pelvic control in the Pilates group. Next, when looking at back endurance, study 2 had established a significant difference existed between back pain and non-back pain sufferers for both the dynamic extensor and Sørensen tests. In this study, the dynamic extensor and McGill lateral tests ($P < 0.05$) indicated significant effects of the intervention on the lower back and obliques. Like the sit-up test, and again possibly just as controversial in its use with those portraying symptoms of back pain, it is interesting that the dynamic extensor test showed a statistical interaction. This is because the Sørensen test, generally associated with discriminatory reliability in back pain studies, was on this occasion not significant. In hindsight, the intervention period would normally be regarded as sufficient to elicit a response in trunk endurance, flexibility and other components of fitness if present, but the findings of this current study suggest it may be necessary to repeat the study with a larger number of participants to obtain more powerful quantitative data.

The back pain questionnaires used in this study, namely the QDS and OLBDQ, are both designed to assess pain-associated disability. In study 2, the QDS questionnaire was used to establish that a significant difference existed between the back pain and non-

back pain groups with a mean disability score of 20 for the back pain and 2 for the healthy control group. The results of study 3 displayed an increase in the perceived disability score for the control group from 12 to 20 (QDS) and from 9 to 11 (OLBDQ) suggesting deterioration of the condition. In contrast, the BodyBalance group showed a reduction in perceived disability from 31 to 12 and 11 to 6 respectively, which indicated a significant improvement. The QDS and OLBDQ could therefore be regarded as a sensitive enough instrument to detect the effect of BodyBalance participation (QDS, $P < 0.01$; OLBDQ, $P < 0.05$), on back pain individuals. Additionally, the post-testing QDS score of approximately 12, although not as low as the disability score recorded for the control group in study 2 that included non-back pain participants, indicated a considerable improvement following participation.

Qualitative research includes many tools that would be useful in investigating pain due to the way perception of pain and experiences often differs from the actual level (Crombez *et al.*; 1996). One such instrument is interviews and these were used to expand and qualify some of the information disclosed within the questionnaires. The objective was to gain an understanding of how a participant viewed both the experience back pain had on their lives and any subsequent impact from intervention. The main themes deduced from their semi-structured format were the participants' impressions of back pain, the extent of their understanding, coping techniques, identity, motivation and achievement. The first theme involved the physical experience of the individual's pain, which could be anything from an ongoing "dull ache" to seizures causing immobility. It affected behaviour and mood state, particularly in terms of sleep disorder and depression,

with depression intensifying due to the long-term chronic nature of the disability. The interviews revealed that, following intervention, three of the interviewees from the BodyBalance group that originally suffered disturbances no longer had interrupted sleep patterns. In addition, they also no longer saw themselves as suffering from back pain despite being cautious that it could return. All three interviewees from the control group, on the other hand, experienced either the same or a more acute experience of pain than at the start of the study along with similar sleep difficulties. The second theme revolved around the individuals' understanding of this condition, a condition not outwardly visible thereby limiting tangible proof of its existence. An important consequence was fear of pain that inhibited activity, which in turn increased associated disabilities. Based upon this idea, the BodyBalance group acknowledged a greater kinaesthetic awareness of sensations post-intervention that signalled potential increases in pain, along with a reduced fear of activities associated with making the condition worse. The benefit to those in the control "workshop" group however, was an understanding that others suffered symptoms and disabilities related to back pain. Next, a real concern of all interviewees at commencement of the study was the belief that any uncontrolled or exaggerated movement would make the feelings of pain worse, so an element of caution became ingrained in every move. Post-intervention the BodyBalance group were now in a situation that they had the freedom to "cope" with most activities recruiting just an element of care so as not to become a "sufferer" again. The control group, on the other hand, still focused continually on preventing the next incident through careful planning of all activities and an awareness of ensuing consequences. Penultimately, "identity" discussed how the effect invoked by the lack of freedom to choose, impacted upon the

need to rely on others alongside feelings of isolation, social withdrawal and being misunderstood. The difference to identity was most apparent in the depression sufferer who was now socialising more and had an enhanced positive outlook than she did at pre-intervention. The final area for discussion was motivation to exercise, more specifically on whether a participant's belief that exercise improved posture and back pain was sufficient to motivate them to change. The BodyBalance group received praise and saw progress, both in their ability to perform movements within the class as well as in reduced pain, motivating them to maintain their exercise programme. The control group remained at the contemplation/preparation stage and gave excuses as to why they could not exercise.

6.6 CONCLUSION

The current study is built upon the premise that individuals with CLBP are likely to benefit from workouts such as BodyBalance. The application of qualitative research methods to this back pain investigation has proved useful in obtaining data due to the discrepancies between actual and perceived levels of pain. As a result, its use strengthens the argument that the workouts help eradicate some of the disabilities brought about by chronic pain and improve an individual's quality of life. BodyBalance is available at numerous leisure centres making it within reasonable distance of many sufferers and therefore could be recommended as a preventative or rehabilitative solution to a common condition. To conclude, it is clear that although some positive outcomes of following the BodyBalance regime appeared to be present in this study, investigations with a larger sample size would be necessary to increase statistical power to the tests.

Chapter 7

The final chapter

“Change will not come if we wait for some other person or some other time. We are the ones we’ve been waiting for. We are the change that we seek.” (*Barack Obama; 2008*)

7.1 Summary

The primary objective of the three-study structure embodied in this thesis was to assess the influence a reasonably accessible “off-the-shelf” studio workout would have on both the physical and psychological symptoms experienced by CLBP sufferers. The purpose of this investigation was therefore to establish whether a viable alternative existed for the high percentage of individuals in the western world affected by this condition. BodyBalance was the exercise programme chosen as the intervention because it maintained standardized choreography for a three-month period and concentrated principally on movements that strengthen the “core”. As such, it was ideal to address the hypothesis outlined upon commencement of the thesis, which stated that “trunk stabilisation benefits will be derived from CS exercises and chronic back pain sufferers would benefit” from such participation. However, being a recently developed programme has its disadvantages, which includes lack of necessary research to justify claims made by its creator. The initial focus therefore sets about to examine the validity of suggested benefits arising from research undertaken on yoga, Pilates, Feldenkrais and tai chi, which are the composite movements of a BodyBalance workout. Adapted to accommodate the outcome of this initial investigation, the thesis then progresses into looking at the effect of the exercise programme on low-back pain.

This final chapter aims to consolidate and summarise the current research project by amalgamating the findings from studies one, two and three. It examines concepts arising out of the literature review in each respective study of the investigation, discussing findings in the light of any interaction applied and, where required, redefines the direction the thesis takes to continue its journey. It allows the relationship between exercise and back pain to be examined, to determine consequences upon the participant, both on a physiological and psychological level. Thereafter, it attempts to consider any implication these findings may have upon the vast choice of exercise programmes that are currently available, particularly when selected by an individual with back pain. To conclude, these studies then discuss the limitations observed during the investigation, alongside the author's recommendations for future research.

7.2 Summary of the Research Findings

Study 1

Study 1 was designed to test the validity of selected health benefits claimed to be attributed to participation in the BodyBalance programme. A repeated measures design assessed the effects of a 12-week exercise programme on a healthy adult population with participants divided randomly between a lecture control ($n = 17$) and a BodyBalance exercise group ($n = 17$). ANOVA was used to determine differences between the groups followed by independent and paired samples t-tests that were used post-hoc. No significant changes occurred in the control group between baseline and post-intervention.

Anthropometric, physiological and biomechanical

It was noted that following BodyBalance intervention, body mass was slightly reduced, although this was indicated only by a trend ($P = 0.051$), along with a significant group reduction in body fat percentage ($P < 0.01$). Mind-body programmes are not specifically designed to elicit a weight loss, as indicated by earlier research into programmes such as Pilates (Jago *et al.*, 2005; Segal *et al.*, 2004). They do not produce the increase in metabolic rate that accompanies other aerobic and cardiovascular programmes. For this reason, it could be suggested that the above changes are more likely to be credited to an increase in lean body mass brought about by the endurance work involved. The fact that girth measures at the waist and hip also decreased ($P < 0.01$ and $P < 0.05$ respectively) indicated a particular effect of such “toning” on the trunk region. Moving on to the remaining components of fitness lower back strength, measured using a dynamometer, increased significantly ($P < 0.01$) for the BodyBalance group. In addition, all five measures of flexibility significantly increase their ROM; namely sit-and-reach test ($P < 0.01$), hip flexion ($P < 0.01$), hip abduction ($P < 0.01$), hip extension ($P < 0.05$) and lateral flexion ($P < 0.05$). This could prove to be of some benefit to back pain sufferers, as there are suggestions of a relationship between lack of flexibility and CLBP. Results of the balance tests were polluted with additional electrical noise that had been present in the laboratory. All data for this variable were therefore discarded and deemed unacceptable for use.

Psychological

Three questionnaires were selected for this study to investigate different aspects of an individual's state of psychological well-being. The "General Health Questionnaire" (Goldberg *et al.*, 1991) administered to participants in week one of classes and at the "post-testing" session, queried how the participant rated their health in the few weeks preceding completion of the questionnaire. The higher the score, the greater the negative symptoms were emphasised. This was reduced by approximately 34% post intervention, displaying a weak trend ($P = 0.059$) towards improvement. The next questionnaire, the "State Trait Anxiety Inventory for Adults" (Spielberger *et al.*, 1970) was used to assess levels of "general" anxiety. This was administered upon arrival at both testing sessions and helped to explore how individuals identified with or "experienced" certain physical and mental areas of their life. There were no significant changes in trait anxiety from baseline for either group. This opposes findings by Kerr *et al.* (2002) who found changes in trait anxiety following a 10-week programme of Pilates training. State anxiety, often used to determine how a participant felt at a particular moment in time, displayed a significant reduction in the BodyBalance group from the start to the end of a one-hour class on three separate occasions. This is in contrast to the non-significant changes displayed in the control group. It is also in agreement with Berger & Owen (1992) and Kerr *et al.* (2002) who found reductions in state anxiety scores following either a class of hatha yoga or Feldenkrais. The last questionnaire, the Profile of Mood States (McNair *et al.*, 1992), examined six subscales comprising of tension, depression, anger, vigour, fatigue and confusion on three occasions. These were at the beginning of the study in week 1, in the middle at week 6 and at the end in week

12. It only found a significant effect of intervention in “tension” at week 12 ($P < 0.05$); no remaining results were significant. The findings of the current study do not support Kolt *et al.* (2000) who found a significant effect of Pilates on four separate occasions over a two-week period when using the POMS-B1.

The findings from this study played an important part in the direction of the thesis. At the outset, when planning the study, it was thought that testing the primary types of mind-body workouts that were available would be necessary to see which would be more appropriate for back pain sufferers. Upon conclusion of this study, it was realised that BodyBalance would be readily acceptable as an appropriate option to elicit changes that could assist in reducing back pain (see p44). The investigation that would be more beneficial at this stage would be to look at predetermined parameters in people that have CLBP and compare them with those that have healthy backs. Such parameters should include balance, posture, core endurance and flexibility.

Study 2

Study 2 tested the musculature surrounding the trunk with the intention of comparing a back pain and a non-back pain group for variables including postural control, trunk strength, trunk endurance and perceived back pain disability. A pilot study conducted prior to testing determined whether static balance was recorded more accurately on a force platform or a pressure distribution plate. GPOWER was then used to determine sample size, whilst independent t-tests assessed differences between groups and Mann-Whitney analysed any non-normally distributed data. Stratified randomisation

allowed for the division between the group based on the presence of pain and a blind draw selected twenty-six participants for each group.

Anthropometrical, physiological and biomechanical

To begin with, under anthropometric measures, independent t-tests displayed no significant differences between the back pain and healthy control groups for body mass or BMI measures. Next, the physiological measures revolved primarily around trunk endurance and postural control. The reason for trunk endurance is that the “core” consists of both abdominal and lumbar regions, so abdominal endurance, isometric lumbar endurance and dynamic lumbar endurance tests would help ascertain whether differences between the groups existed. Abdominal endurance, measured using a sit-up bleep test, was significant ($P < 0.05$) with the “healthy” control group maintaining a longer test time. There was also a significant difference in the “Sørensen isometric trunk extensor test” ($P < 0.05$) between the two groups, again in favour of the control group. This corresponds to the findings of Tekin *et al.* (2009) and Latimer *et al.* (1999) who demonstrated that individuals with back pain incurred shorter isometric hold-times. There was a highly significant difference in dynamic back endurance measures ($P < 0.01$) where participants performed dynamic extensions off the end of a raised bench according to the criteria given for the 60-second test. Results from this study established those with healthy backs produced 150% the number of repetitions achieved by the back pain group. In addition, strong correlations were noted between isometric back endurance and dynamic back endurance ($r = 0.41$; $P < 0.01$), both of which correlated with abdominal endurance in the form of sit-ups ($r = 0.47$, $P < 0.01$; $r = 0.61$, $P < 0.01$).

Finally, static and dynamic balances are often considered reasonable indicators of postural control. No significant differences were exhibited in the balance measures between these two groups. These results conflict with similar studies by Mientjes *et al.* (1999), Byl *et al.* (1988) and Volpe *et al.* (2006) who discovered postural sway to be greater in low-back pain participants than in a healthy participant group.

Psychological

The psychological information required for study 2 differed from the first study, as it was needed to investigate the impact of living with back pain rather than how exercise treatment affects mood states and anxiety. The Quebec Disability Scale (Kopec *et al.*, 1995) provided a measure, from the individual's perspective, of the extent to which back pain affected their daily lives. In addition, Kopec *et al.* (1995) recommended its use as an outcome measure in clinical trials. A significant difference ($P < 0.01$) was calculated between the control group and the back pain group, with the latter displaying a perceived disability ten times greater than the control. Disability arising from the questionnaire also correlated with isometric back endurance and dynamic back endurance ($r = 0.33, P < 0.05$; $r = 0.36, P < 0.01$).

Overall findings from this study support the idea that trunk endurance is lower in individuals affected by the symptoms of CLBP. It would therefore be of benefit to include it in the final study by using solely a back pain population. Likewise, back pain disability questionnaires proved useful in study 2 for determining the perceived extent of

pain and the effect on an individual's life, so again would be a useful tool in the test battery for the final study.

Study 3

The final study in this trilogy focused on the effects of BodyBalance exercise and its impact on individuals suffering from back pain. A number of criteria were stipulated to participate in the study and the names of those who fulfilled these were divided, using a blind draw, between a BodyBalance group (n = 8) and a workshop control group (n = 7). Half of the selected volunteers were then given the option to take part in interviews. A repeated measures design assessed the impact of 10 weeks of BodyBalance training. Independent t-tests were used to establish baseline differences, ANOVA calculated the effect of the interaction on normally distributed data and Mann-Whitney on all other data. Interview data was transcribed into themes using Interpretive Phenomenological Analysis. Finally, one interviewee was selected as a case study due to the nature and extent back pain had influenced her life.

Anthropometric and physiological

The BodyBalance and control groups displayed no significant differences at baseline for any of the anthropometric or physiological parameters being measured. Consisting entirely of participants with CLBP, it showed no significant changes in either group for body mass or BMI. As such, it did not substantiate the findings of study 1 where a trend in healthy participants resulted in weight loss along with a significant reduction in body fat composition. However, it does agree with findings of

investigations by Segal *et al.* (2004), Sekendiz *et al.* (2007) and Gutman *et al.* (1997) who looked at non-back pain groups participating in Pilates and Feldenkrais workouts.

Physiological variables assessed consisted of trunk endurance, back strength and flexibility. Trunk endurance tests included the Sørensen, 60-second trunk extensor, sit-ups, McGills lateral and McGills flexor tests. The Sørensen test has been used as a measure of fatigue times in a number of studies because it does not require the maximal effort an individual with acute back pain would be unable to give. Regarded as the most frequently reported test in Isometric Back Endurance literature (Moreau *et al.*, 2001; Coorevitis *et al.*, 2008), it showed a significant difference existed between the back pain and non-back pain group for study 2. This supports the findings of Latimer *et al.* (1999), who agreed the test could discriminate between those with and without back pain. In study 3 the difference, although not significant, indicated a trend ($P = 0.055$) that could possibly be influenced by the use of a larger participant group in subsequent studies. These findings also do not agree with Mannion (2001) who found Sørensen endurance times increased significantly on back pain participants following physiotherapy, muscle conditioning and low-impact aerobics. An alternative conclusion would be that the intervention, the extent of input that back pain participants were able to commit, or the exercises included within the choreography were not enough to elicit sufficient change within the time allocated. The dynamic trunk extensor endurance, however, was significant ($P < 0.05$) implying a positive effect resulted from the interaction. This may also be considered a factor that helps identify back pain, as study 2 showed significant differences existed for this variable between the back pain and non-back pain groups.

The same applies to abdominal endurance where the number of sit-ups in study 3 increased significantly ($P < 0.01$) following intervention and, like the dynamic extensor endurance results in study 2, depicted a significant difference between back pain and non-back pain groups. This supports the findings of Herrington *et al.* (2005). Furthermore the McGills tests, performed for the first time in this thesis to cover other areas of endurance, resulted in a significant effect for lateral musculature ($P < 0.05$) but were not significant for flexor endurance ($P = 0.07$). Again, there is some concern as to whether the effect would change with a larger group size.

Back strength measure for study 3 proved not significant for the back pain participants. During study 1, with healthy participants, the effect on back strength following BodyBalance was highly significant. A further longitudinal study, with Pilates undertaken over five weeks on back pain participants (Sekendiz *et al.*; 2007), was also significant. This shows little consistency in the outcome for strength following a course of exercise. The findings again may need to be reinforced by repeating the study using a larger back pain group.

Finally, flexibility was a variable clearly influenced by BodyBalance in study 1 with all five measures recorded during that investigation with healthy participants producing a significant effect after exercise intervention. Unfortunately, with back pain participants, this has not produced the same results. This could have been due to less effort during the workout because of the fear of pain, limited ROM due to inhibited

movements or the longer lead-time before they were able to perform the move with the same ROM as the non-back pain group.

The first flexibility test, the sit-and-reach, produced a significant effect of BodyBalance on healthy participants in study 1 but proved not significant for the current study with back pain individuals. This is in spite of the fact that the hip flexion test, which requires a similar movement, was significant ($P < 0.05$) on this occasion. The finding that hip extension, in addition to the sit-and-reach, was not significant does promote the idea of repeating the study with a greater number of participants. The remaining measures, hip abduction ($P < 0.01$) and lateral flexion ($P < 0.05$) were similar to study 1, producing an increase, irrespective of the presence of back pain.

Biomechanical

The main areas for consideration under biomechanics in this study are the respective balance measures. Under the static Romberg test, using the dominant leg with eyes-open condition, ANOVA indicated a significant effect ($P < 0.05$) of BodyBalance training in creating a reduction in the COF travelled way on a pressure plate. Study 2, however, depicted no difference in this parameter between the healthy and back pain group, which would probably suggest that the change in study 3 might be attributable to BodyBalance. No significant differences were recorded for the eyes-closed condition, possibly because this is not an area trained during the workout. Dynamic balance, recorded as time in balance on the stabilometer, was not significant which reinforces no effect of the intervention. This would again make sense, as movements included in the

workout are slow and controlled, including very little need to recover from loss of balance whilst in motion. Following Hrysomallis *et al.* (2006) no attempt was made to infer static balance on dynamic or vice versa.

Psychological

The psychological data included within this study was designed to provide a more comprehensive insight into otherwise immeasurable variables by including back pain disability questionnaires, interviews and a case study. In the first instance, independent t-tests at baseline showed no significant differences between the groups for either of the two questionnaires. The QDS questionnaire had already established that a significant difference existed between individuals with and without back pain in study 2. In study 3, it also showed that a significant effect had occurred ($P < 0.01$) following intervention, with the back pain disability recorded for the control group deteriorating by 71% and improving by 61% for the Bodybalance group. These findings do not indicate that the pain experienced was equivalent to someone with a healthy back and had been completely eradicated, but more that there was a considerable reduction in the way back pain was perceived to influence the participant's life. Likewise, the OLBDQ displayed a significant effect ($P < 0.05$) with the score for disability having deteriorated for the control group, albeit by only 21%, but having improved by 45% for the BodyBalance group. These two questionnaires have proved quite advantageous in trying to understand some of the ways a sufferer's quality of life could be enhanced and were complemented even further by the interviews that took place.

The use of interviews allowed for an even greater depth of understanding to be added to information extracted from the questionnaires. Two interviews took place for selected individuals ($n = 7$), one at the beginning of each testing session. The themes extracted from the first interview consisted of back pain experience, understanding pain, coping strategies, questioning own identity and the motivation to exercise. A sixth, achievement of goals, was added at the second-interview stage. Each of these will now be summarised in turn. Firstly, “experience of pain” helped to identify the symptoms that individuals were feeling. This included a description of the pain, with labels such as dull, sharp, continuous, intermittent, regular and uncomfortable. In conjunction with the description, it identified emerging conditions such as fatigue, lack of concentration, tension, stress and frustration. The most severe sensations detected were short-term paralysis and depression. Assessment of all these variables at the second interview helped to establish whether changes had occurred over the duration of the study. Interestingly, three of the interviewees from the exercise group stated that the back pain had virtually disappeared. The fourth indicated the severity of the pain had diminished. Within the control group, two interviewees felt there had been no change and one felt the symptoms had intensified. This study does seem to support the idea that the experience of back pain can be improved through “core” type exercises. This would include improvements in symptoms for the BodyBalance group that would enhance their quality of life by allowing individuals to perform functional tasks, such as putting children to bed or sitting in an upright position for any length of time, with greater ease. Secondly, grounded within the “understanding pain” theme, was the concept that “lack of knowledge” intensified the symptoms of pain. Participants at the first interview felt that

the more they could identify events that would trigger an attack, the more they could take action to reduce the intensity or even prevent an occurrence. This would help to reduce some of the associated concerns, in particular fear of pain, immobility and spasms. Fear, in any form, would increase avoidance leading to muscular disuse and acquired disabilities. Following intervention, the BodyBalance group gained a kinaesthetic awareness through experiencing changes in their physicality that gradually allowed them to extend their comfort zones. The control group felt that they had gained an appreciation that they were not alone in the symptoms they were experiencing, but other than “food for thought” there did not seem to be any tangible benefit of the knowledge gained from the workshop and its practical application. Thirdly, “coping strategies” allowed the individual to use a variety of techniques to be able to cope with everyday activities, thereby allowing some semblance of a “normal” life. Across groups, a main first order theme was adapting and restricting movements, generally by limiting the range, type and duration. Further prominent features included therapies such as massage, medication, low-impact exercise formats like swimming and adjusting physical objects to alleviate pain. Where back pain had improved post-intervention in the exercise group, the objectives had changed to maintaining this status quo using tools such as correct lifting techniques or continual readjustment of posture to prevent a recurrence of the pain. Where considerable pain still existed, for the control group and one member of the BodyBalance group, the priority lay with self-management to prevent an acute attack. Fourthly, “identity” was a slightly different aspect of pain that dealt with issues such as isolation, depression, social withdrawal, reliance and misunderstanding. It influenced an individual’s freedom of choice and the belief in their ability to complete tasks. It caused

sufferers to withdraw from social circles rather than explain to others who “did not understand” why they could not do something because of pain. This in turn led to elements of anger and frustration. Most of these concerns remained post intervention for the control group. In addition, for one member of the BodyBalance group, depression continued to remain an issue, although the feelings of hopelessness were less intense. Next was “motivation”, the last of the themes categorised at the preliminary interview, which investigated the regularity of exercise and the effect created by intrinsic and extrinsic factors. It looked at the relationship interviewees had with the suggestion that exercise affects posture that in turn influences back pain. Furthermore, it looked at the manner in which fear was displayed by a number of limitations, self-imposed or otherwise, such as the perceived intensity of pain or time to commit to exercise. Whether the individual would be able to overcome these obstacles varied between the groups. The post intervention interview still showed the control group to be in the contemplation stage of change. Interviewees had thought about exercise, were aware of the benefits and what they had to do, but had no immediate plans to initiate action. The exercise group, who had noticed positive results through participating in the workouts, were much more ready to commit to continuing an exercise programme. After having worked consistently for the 10 weeks, they seemed to want to avoid the possibility of a relapse. Their plans to exercise in the near future were much more optimistic and concrete, most had also exercised regularly in the few days between the last BodyBalance session and the interview. Finally, “achievement” was included at the post intervention interview to determine whether preset goals had been met in terms of pain control, prevention, posture, activity levels, confidence or quality of life. The control group knew what they

should be doing but had not really progressed beyond the contemplation stage. From the BodyBalance group three of the four interviewees felt they had met their respective targets whilst one said that she wanted to build on the strength she had gained through participation and, although she had not met her goal in its entirety, was on the way. This group also provided one participant whose interview data was rich enough to be considered independently as a case study.

The case study provided a good example of the difference a mind-body workout can make to an individual. It discussed the experiences from a single person's perspective rather than a group, highlighting the more detailed specifics of how disabling the condition can be and how much impact something as simple as a few weeks exercise can have upon the individual. It allowed the interviewee to tell her story in terms of her life, her family and her career, as opposed to her contribution to the effects of the group to which she had been assigned. In essence, the tale involved a mother with three young children who came to the first interview unable to maintain her body in an upright position whilst seated. She performed every movement with the caution often recruited by those whose every physical adjustment can be the trigger for inflicting immense pain. Following three successive pregnancies, she now lived with a misaligned posture, pubic symphysis disorder and low-back pain. A physiotherapist, unable to treat her in her present condition, had referred her onto hydrotherapy and agreed to her participation in the current study. Sarah (pseudonym), the young woman in question, had been very active prior to this but her condition now left her unable to function and meet the requirements of her own needs and those of her family. Physically, the laboratory tests

exposed her inability to stand and balance in an upright position. She had the lowest results of all the study 3 participants in six of the tests including trunk endurance. In addition, the back pain questionnaires had assessed her as perceiving to experience “moderate to severe” disabilities in her daily activities. For the first few sessions, she was unable to perform a number of moves with the correct technique and was carefully monitored. Over the duration of the first few weeks changes started to become apparent. The alignment of her body segments improved, particularly around the region of her cervical and thoracic vertebrae. Her flexibility increased, most noticeably for lumbar flexion. She became more able to lie supine and sit upright without excessive distortion in her spine. Towards the end of the intervention period, Sarah felt the pain no longer existed or dominated her life. She could function sufficiently to be able to bathe, lift and play with her children without feeling dependent upon her husband. She was no longer exhausted all the time, as she no longer worried about the pain or constantly having to plan her every move. She was also managing to sleep throughout the night. Post-intervention tests displayed improvements in the majority of her physiological and biomechanical tests. In fact, Sarah now perceived the disability resulting from the back pain to have diminished by 82% on one questionnaire and eliminated on the other. Her headaches and other feelings of numbness had disappeared. Ultimately, this release from the fear of impending pain had left her more able to enjoy and participate in all aspects of her life.

7.3 Implications

Findings from the research contained within this thesis provided a number of suggestions regarding exercise and back pain. Examining a wide selection of parameters, it aimed to review the results of existing studies in mind-body exercise and apply it to a modern variation. The complete package of these three sequential studies therefore aspired to allow for a well-researched insight into both the benefits of BodyBalance exercise on healthy participants as well as those afflicted with back pain. In addition, it attempted to differentiate core parameters between the two participant groups to see if any influential factors existed that could prove useful in the search to regain a healthy back. Based upon the findings of the first two studies, it then endeavoured to establish the practicality of using BodyBalance on individuals with back pain as an additional form of treatment or as a prevention programme.

The findings arising from study 1 suggest that a healthy individual taking part in BodyBalance over a sufficient period, might achieve reduced body mass and body fat percentage. As most of the reductions in girth were discovered around the trunk region, more specifically around the waist and hip, this could be of interest when dealing with individuals prone to storing excess subcutaneous fat around the stomach area. Isometric back strength improved significantly indicating again the possible impact of the workout in improving the functional ability of the back to cope with challenges imposed by daily activities. Flexibility also plays an important role, as a balance of opposing muscle groups prevents a predominance of one group thereby minimising the risk of back complications. Significant increases in all five measures around the trunk could be due

to a possible lengthening of tense, shortened muscles that in time could lead to improved postural alignment. No significant differences were noted, however, for heart rate, pulmonary function or BP indicating that BodyBalance specifically is not necessarily the best option if looking to improve these variables. Alternative suggestions in this situation could be formats such as aerobics that incorporates either a greater cardiovascular component or an emphasis on breathing. Finally, there were differences exposed in some of the questionnaires completed during the study. The GHQ, although not significant, indicated a possible trend ($P = 0.059$) that reinforced the idea of individuals feeling the general health and quality of their lives had improved. Accompanying this was a significant improvement in state anxiety due to class participation. This would strengthen the argument for BodyBalance as an ideal workout to reduce stress and encourage relaxation.

Study 2 was designed to evaluate the use of balance, trunk endurance and perception of back pain disability as indicators of CLBP in a group consisting of back pain sufferers and a second “healthy” control group displaying no apparent symptoms. These parameters were selected in advance of their use as a tool in study 3, the final investigation of the series. Starting with balance, findings from the current study found no significant differences between the back pain and the control. One possible reason may have been that participants of both groups had not incorporated any form of training that refined balance skills within their daily activities. This may have been for a number of reasons including the sedentary nature of an individual or avoidance of movements that inflict pain. Next, the results of the Sørensen and dynamic 60-second extensor

endurance test were significant, which is in keeping with results from previous studies of a similar nature. In addition, the results for abdominal endurance also highlighted a significant difference between the groups. Therefore, in light of the relationship between back pain and trunk endurance, there is the prospect of BodyBalance rectifying weaknesses in trunk endurance to create a stronger, healthier back with less pain and improved balance. Finally, psychologically, the results produced a highly significant difference in the manner a sufferer perceives pain to affect their daily lives as opposed to a non-back pain sufferer. The QDS, in keeping with the current results and those of earlier studies, can be regarded as a sensitive enough instrument to assess the impact of this back pain disability and to measure such changes over time.

The final investigation in this thesis, study 3, sought to direct the findings of studies 1 and 2 into research founded upon the aim that participating in a BodyBalance programme over 10-weeks would enhance trunk endurance and reduce symptoms of back pain. It evaluated balance along with strength, flexibility and endurance of the trunk. This accompanies a selection of back pain disability questionnaires and interviews for a more personal insight into the psychological influences surrounding an individual's life. Balance, the first of these variables, displayed a significant effect only in the quiet standing stance. The more refined the ability to maintain this control, the more likely would be a reduction in the fear of movements resulting in back pain or similar responses. This improvement would also be beneficial, particularly as people get older, because balance deteriorates with age contributing to a greater likelihood of falls. It was also not found in the first study incorporating participants with healthy backs, possibly

because the muscles function adequately and would therefore not increase to the same extent as a result of taking part in regular exercise. Moving onto lower back strength, the fact that it did not improve in back pain participants undertaking BodyBalance but it did in healthy participants within this treatment, may be because of the reluctance of sufferers to recruit the lumbar muscles for a large portion of the study. It would therefore be necessary to continue the exercise programme for a longer period with CLBP sufferers to determine whether this would elicit the necessary changes. The last physiological measure is trunk endurance and the most important test result with respect to this is the Sørensen test, which displayed only a trend ($P = 0.055$) towards improvement. Due to research proposing endurance to be an indicator of future back pain, one could assume that an increase in this variable would indicate future improvements in the intensity of pain related symptoms. This, in conjunction with the significant difference in isometric extensor endurance established in favour of pain-free individuals in study 2, suggests again that a study with a longer intervention period along with a larger experimental group could be required to increase result validity. To extend this further in terms of practical applications, it would imply that participants would need to look at committing to an exercise programme for slightly longer than is normally expected to obtain the desired results. The relationship between back pain and exercise in study 3 could also be reinforced by considering the increases in three of the remaining trunk endurance measures. In summary, endurance could be used to advocate BodyBalance as a means of strengthening the trunk and reducing back pain. Alternatively, it could be suggested that the increases should be attributed to a reduction in fear or anxiety that inhibited maximal effort on the first attempt at the tests. The final parameter to consider in terms of its

implications is therefore psychology, including the back pain questionnaires that displayed a positive effect of the interaction on the exercise group. Such data has been instrumental in determining the hold this pain has on an individual as well as being a simple test to implement. Combined with data gathered from interviews, it provided a good indication of the disabilities faced by sufferers on a daily basis and the relief encountered by the individual as the pain improves.

The evidence extracted from the three studies above suggests there is a difference in trunk endurance measures and perceived back pain disability according to pain status. Abdominal and isometric extensor endurance measures were greater in participants with no history of back pain along with minimal perceived disruptions to their daily activities. BodyBalance is a mind-body programme available to individuals irrespective of their fitness levels or CLBP status. There is an indication that it may assist with a gradual reduction in weight and body fat but it is not a programme with an emphasis on the cardiovascular component. If weight loss were the objective then other workouts formats would be more appropriate. Similarly, it does not influence BP, heart rate or lung capacity. However, it may be used to address flexibility imbalances or weaknesses, thereby improving postural alignment in addition to reducing state anxiety. In situations involving participants with CLBP results have shown BodyBalance can improve balance, possibly by reconditioning muscles in the trunk that were neglected due to fear or anxiety. This in turn would help aid general physical tasks in addition to reducing falls, which are particularly common in older individuals. Most of the results indicated increased endurance, again in the trunk, showing a reduction in the chance of future back

pain. It also produced a reduction in the disability perceived by the individual that empowers the individual to regain control of their decisions and choices.

7.4 Limitations

The methodological approach, utilised for the studies contained within this thesis, encountered a number of limitations that need to be acknowledged. A good point to initiate this discussion would be the choice of methodology itself, as it has proven somewhat varied over the course of this research. Firstly, two of the studies adopted a longitudinal design and one a cross-sectional design, although both methods are widely used within applied research. The approaches themselves also varied from the quantitative method, using experimental research and questionnaires, to a mixed-method approach that included the former alongside interviews and a case study. The reason for the move towards the latter was that the nature of pain and impact of such disability on an individual could not be fully understood by experimental methods alone. This opened the research design up to deviating from the “truth” as sought after by quantitative researchers. The advantages of this combination, however, was the complementary manner in which information gained from the participants’ perspective added and qualified quantitative data providing richer, more in-depth details to the findings.

A noticeable limitation of the study relates to the representative nature of samples and group sizes, particularly in study 3. The participants required for this were individuals with chronic back pain who were able to commit to undertaking three BodyBalance classes per week over ten weeks. This attracted applicants within easy

reach of the University campus. It could be suggested that the general population that would benefit most from such a treatment would be those within easy reach of leisure centres or possibly doctors' surgeries and other points of referral, so there is some question whether the sample used in this instance would be truly representative. The nature of back pain also limited the number of volunteers applying to participate leaving not only the lack of applicants to allow for true randomisation but insufficient participants to facilitate statistically significant findings. The sampling method for study 2 also needed to be stratified, once the back pain status of individuals had been determined, reducing the randomness of group selection. Furthermore, "blinding" of participants in all groups was an issue because at various stages the investigator had knowledge of back pain status or group allocation. This was especially applicable to studies 1 and 3, the longitudinal investigations. A number of controls instigated at the start allowed a blinding protocol to be adhered to during the selection process and preliminary testing but, due to the need for the researcher to help monitor the sessions and maximise attendance, there was concern for potential experimenter bias during the post-intervention testing sessions. There also remained the requirement that, for the purposes of obtaining the PhD, it was preferable that the researcher conducted testing sessions.

A further limitation imposed by this study concerns both the definition of chronic back pain and its assessment. For the purposes of studies 2 and 3, the researcher chose a definition that embraced pain for a minimum of three months duration over the preceding three years. There are in existence however, alternative definitions that may provide a

stronger and more clearly defined back pain group. Assessment was also conducted utilising self-reported measures based upon the perception of the individual at that specific point in time. It may be better to establish a more clinical measure of back pain to substantiate the degree of back pain or request data from appropriate personnel such as physiotherapists. Such information would also prove useful as a safety measure to protect back pain participants during testing or exercise interventions. A well-defined back pain group may also help in understanding why different responses were found in certain parameters between back pain and healthy participants.

The last limitation to be addressed relates to the pressure-plate equipment used in studies 2 and 3. Data derived from a force platform in study 1 were discarded as it contained errors due to noise pollution. A pilot study conducted within study 2 established the pressure plate to provide more reliable measures of “static balance”. The research on the pressure plate does not currently include studies on humans for this parameter so direct comparisons were not possible.

7.5 Recommendations for future research

This thesis has exposed a number of relevant issues concerning research into mind-body exercise and back pain. The main suggestion would be to encourage more focused investigations based upon the findings of the three respective studies contained within this thesis. The first recommendation would be to repeat the quantitative component of study 3 with a larger sample size. Qualitative methods proved extremely advantageous in terms of the data ultimately derived but quantitative measures performed

with the minimum sample size, as determined by a power analysis calculation, would add greater substance and validity to the findings. Next, within the first study there was also a trend towards weight loss and a significant reduction in body fat percentage from an exercise programme that is relatively low-impact. Despite not being a cardiovascular workout, it still managed to significantly reduce girth measures around the waist and hip. Further research to help investigate these findings would help reinforce whether the use of the programme would help in the fight against obesity in the Western world. Thirdly, static balance was found to have improved for back pain individuals in study 3 following the BodyBalance treatment. Further studies using slightly older participant groups could also provide interesting results if focussed towards whether the workout treatment could influence the number of falls. The method of balance data collection used in studies 2 and 3, the pressure plate, also has very little research available and therefore additional research is recommended using this equipment on human participants. Fourthly, the findings from the current investigation produced differing results for parameters such as flexibility and strength for the healthy and back pain BodyBalance groups. A future study using a “healthy” control group alongside a back pain BodyBalance group could help establish whether the inhibitions provoked by pain are responsible for producing a much slower rate of improvement in the latter. Similarly, studies investigating the impact of BodyBalance on other disorders with “subjective” levels of disability perceived by the individual, such as Myalgic Encephalomyelitis (M.E.), could be another area to pursue. Finally, research on alternative programmes could be undertaken to determine whether they may be better suited to improving balance, core strength, flexibility and endurance.

An area that was not researched in the current studies was posture. However, a distinct change was noticed in the posture of the case study participant by the investigator, the participant herself and her physiotherapist. A more efficient alignment would assist in reducing unnecessary forces or loading on the spine reducing the likelihood of ongoing episodes of pain. A more biomechanical approach could be taken to investigate the impact of mind-body exercise on posture in conjunction with investigating whether differences are noted in this parameter for back pain participants.

The last area of research to be recommended concerns various investigations with a psychological undertone. This is because greater information into the perception of back pain could be beneficial in gaining an understanding of the experiences of sufferers in terms of impending fear and the downward spiralling effect resulting from inhibited activity. Included within this could be qualitative studies that would help determine how different people respond to such programmes and ultimately how it could aid their ability to recover. It could also be interesting to investigate how these would change following alternative regular exercise formats.

7.6 Conclusion

The objective of this thesis was to verify benefits that could be gained from participating in modern day mind-body programmes. To recap, it is essential to outline the problem areas that it aims to address. Firstly, CLBP is a widespread consequence of the often sedentary, stressful lifestyles encountered by individuals within this society. Consequently, with up to 90% of the population (Herring *et al.*,

1995) reporting an occurrence of low-back pain at some point in their lives, this condition inflicts a heavy financial burden upon the sources of the state-funded NHS. For industry, it encounters a cost in terms of the number of working days lost each year. For the individual it reduces the quality of life, in some cases leaving them unable to cope with everyday tasks including caring for themselves, their families or fulfilling the requirements of their employment. Therefore, this thesis seeks to investigate some of the differences in core strength or responses to BodyBalance between low-back pain individuals and those with “healthy” backs.

The respective investigations contained within the boundaries of the thesis have led to a number of important contributions in knowledge pertaining to the field of health and exercise research. In study 1, it found a significant improvement in body fat percentage and a reduction in girth around the hips and waist. It also determined there was a significant difference in flexibility and lower back strength in healthy participants. Study 2 then established a significant difference in trunk endurance and a back pain disability measure between a group with chronic back pain and a non-back pain group. Finally, study 3 resulted in mixed results for trunk endurance, back strength and flexibility for back pain participants. This may have been due to small group sizes. However, the psychological disability questionnaires, interviews and case study support the improvements being experienced by individuals.

Overall, this thesis has established that BodyBalance may be regarded as an exercise format that can be beneficial to the healthy population. It has also reinforced some of the findings proposed in earlier research surrounding physical and psychological benefits of exercise for those with back pain. Furthermore, not only has it contributed to the library of mind-body research already in existence, in terms of a study that incorporates reasonable control measures, but additionally it has utilised a mixed-method approach when dealing with investigations related to mind-body exercise and pain. Finally, it has substantiated with the use of qualitative research, that a back pain sufferer can experience many improvements to their quality of life through incorporating a programme similar to BodyBalance in their daily routines.

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APPENDIX**STUDY 1**

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|--------------|---------------------------------------|
| I | BodyBalance Brochure |
| II | Advertisement in Guardian |
| III | BodyBalance Poster |
| IV | Article from staff website |
| V | Cover letter to HLQ |
| VI | Research Participant Information |
| VII | Health Questionnaire |
| VIII | Selection Advice Correspondence |
| IX | Preliminary Test Information |
| X | Consent Form |
| XI | Diet and Activity Record Sheet |
| XII | BodyBalance Instructor Correspondence |
| XIII | Post Intervention Test Information |
| XIV | Data Collection Sheet |
| XV | Girth Measurements |
| XVI | Skinfold Measurements |
| XVII | Vitalograph Test Instructions |
| XVIII | Balance Formulae |
| XIX | GHQ-12 |
| XX | STAI-Y1 and STAI-Y2 |

XXI	POMS-A
XXII	BodyBalance 25 Choreography
STUDY 2	
XXIII	Posture Study Poster
XXIV	Health Questionnaire
XXV	Research Participant Information
XXVI	Selection Advice Correspondence
XXVII	Consent Form
XXVIII	Test Day Information
XXIX	Data Collection Sheet
XXX	Quebec Back Pain Disability Scale

STUDY 3

XXXI	Exercise & Back pain Flyer
XXXII	Exercise & Back Pain Poster
XXXIII	Health Questionnaire
XXXIV	Consent Form- Control Group
XXXV	Consent Form – BodyBalance Group
XXXVI	Data Collection Sheet
XXXVII	BodyBalance 43 Choreography
XXXVIII	Physiotherapy Workshop 1
XXXIX	Physiotherapy Workshop 2

XL Semi-Structured Interview Format

XLI Oswestry Disability Index

XLII Risk Assessment Forms

XLIII Published Paper from Thesis