

Feldenkrais Method balance classes are based on principles of motor learning and postural control retraining: a qualitative research study

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Abstract

Background Feldenkrais Method balance classes have been found to be effective in improving balance in recent studies, but there has been little research into possible mechanisms behind the effectiveness of these classes. Indeed, there has been little research into the content of any balance training classes.

Objectives To analyse the content of a series of Feldenkrais Method balance classes to gain an understanding of how the results in these studies may have been achieved and the principles through which the method may be effective.

Design Qualitative research approach (content analysis).

Method Feldenkrais Method Awareness Through Movement lessons were transcribed and the contents were analysed. An intercoder reliability study was undertaken.

Results The content analysis revealed that the classes used motor skill acquisition elements of internal feedback, repetition and variability of practice using an exploratory learning approach. Postural control skills of intersegmental coordination of ankle/hip/trunk synergies were practised, with control of the centre of mass over the base of support explored in anterior/posterior, medio/lateral, diagonal, rotational and circular directions. Key findings were the extensive involvement of trunk flexibility and control in the balance activities, and also the intensive attention to internal feedback which was linked to body awareness training.

Conclusion The Awareness Through Movement lessons contained many elements consistent with current theories of motor skill acquisition and postural control, providing a sound theoretical basis for the effectiveness of the Feldenkrais approach in improving balance. The methodology used in this study may provide a useful model for similar investigations into other balance training approaches.

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Introduction

There has been increasing interest in strategies/approaches to improve balance, with particular attention paid to reducing falls in older people [1]. Interventions using balance training have been found to be more beneficial than programmes based on strengthening, flexibility or walking [2]. The Feldenkrais Method was developed over several decades by Dr Moshe Feldenkrais (1904–1984), an Israeli scientist and Judo mas-

ter with a pioneering interest in human movement from a dynamic systems perspective. The Feldenkrais Method Awareness Through Movement lessons are an approach to movement learning in which participants are verbally guided through movement sequences aimed at improvement of body awareness and movement organisation [3]. Stephens *et al.* [4] have proposed that ‘this process facilitates the learning of strategies for improving organisation and coordination of body movement by developing spatial and kinaesthetic awareness of body-segment relationships’ (p. 1642).

Among the hundreds of lessons that Dr Feldenkrais created [5], many are suitable for balance retraining. There is evidence of the effectiveness of the Feldenkrais Method for this purpose [6–12]. Awareness Through Movement lessons

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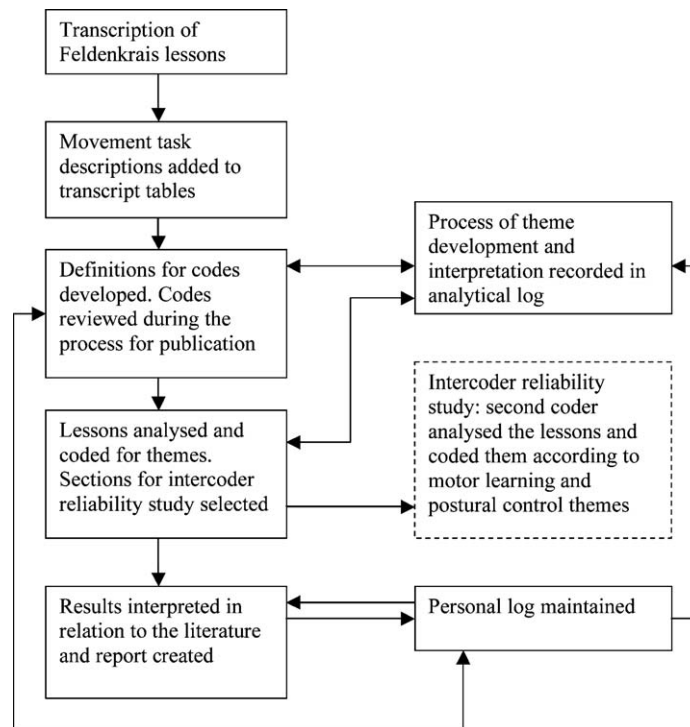


Fig. 1. Methodology of content analysis.

have been found to improve balance measures and balance confidence in older adults [6–9], and also in individuals with multiple sclerosis [12] and chronic neurological deficits following stroke [10]. Older adults attending Awareness Through Movement lessons made significant improvements in activities-specific balance confidence questionnaire scores ($P=0.005$), gait speed ($P=0.017$) and four square step test time ($P=0.022$) compared with a control group [11]. However, no systematic analysis of the content of the lessons has been performed to date. Indeed, there has been very little systematic analysis of the content of any balance retraining approach described in the literature. The purpose of this paper is to provide such an analysis, and to gain an understanding of how the results in these studies may have been achieved and the principles through which this method may be effective. The research question was: Can the mechanisms by which Awareness Through Movement lessons improve balance be identified using content analysis? A further research question was: Is this methodology suitable for investigating the content of other approaches to balance retraining?

Methods

A qualitative research approach was adopted, and content analysis, which is a form of document analysis specifically about communication that has already been captured [13], was identified as being the most suitable analytical approach

for this study. The flow chart in Fig. 1 illustrates the methodology used to conduct this investigation. The left-hand column describes the activities that were undertaken, and the reflective process of the first author is described in the right-hand column.

Transcription of lessons

The 16 lessons of the Getting Grounded Gracefully [14] series of Awareness Through Movement lessons have been recorded on CD and formed the data for this study. Each lesson was different and consisted principally of verbal movement instructions to the participants, interspersed with instructions of what to pay attention to during the movements. A summary of the lessons is presented in Table 1. Transcription resulted in 160 pages of data for analysis.

Description of movement tasks

Each instruction in each lesson was then described as a movement task, so that the actual content of the lessons was clear in terms of movement analysis. For example, the instruction: ‘Imagine you’re standing on a clock–12 at toes, 6 at heels, 3 to the right, 9 to the left. Tilt from 3 o’clock to 9 o’clock’ was described as ‘Weight shift from left to right in standing’ in a column marked ‘Movement task’. This process is illustrated by the excerpt from a lesson transcription displayed in Table 2.

Table 1

Summary of 'Getting Grounded Gracefully', Feldenkrais Awareness Through Movement lessons.

- 1: **'Turning with the whole body'**. Rotation in sitting. The connection between the head and pelvis through the spine is established. It starts to build body awareness of the ribs and pelvis, and starts to improve mobility in the ribs, chest and spine. Confidence in sitting balance is expanded.
- 2: **'Transferring weight'**. Side bending and lateral weight shift, principally in sitting. The relationship between weight shift from side to side and the involvement of the ribs in this movement is established and explored.
- 3: **'Activating the flexors in sitting'**. Forward weight shift in sitting. Exploration of control of the centre of mass over the base of support in the anterior/posterior direction.
- 4: **'Standing up from a chair, part 1'**. This lesson is concerned with a smooth and controlled transition from the stable position of sitting to the less stable position of standing. Sit to stand combined with turning is also explored.
- 5: **'The feet, the ankles and the ground: waking up your balance sensors'**. This lesson is mostly performed in sitting and is about flexibility and movement control of the foot and ankle.
- 6: **'Standing balance and the pelvis'**. Control of the centre of mass over the base of support in standing. Exploration of balance on a static base of support by moving the pelvis in various directions, with various configurations of the feet producing varying degrees of difficulty.
- 7: **'Introduction to walking'**. This lesson progresses from the previous lesson – continuing to explore movements of the pelvis over various static bases of support. There is a progression to circular movements of the pelvis over the various foot configurations.
- 8: **'Standing as balancing'**. Progression from the two previous lessons. The emphasis changes from concentrating on the movement of the pelvis to paying attention to the pressure created under the sole of the foot by the various weight shifts.
- 9: **'Finding your feet'**. Continues previous themes but change of focus in this lesson from differentiating pelvic and head movements to holding the trunk rigid through most of the lesson, so that maximal participation from the ankles is achieved.
- 10: **'Standing up from a chair, part 2'**. This lesson is again about sit to stand, with particular focus on the role of the spine, and thoracic extension in particular. There is much practice of moving forwards in space.
- 11: **'Walking along a line'**. Mostly in stride stance, with diagonal weight shift on to a single leg. The practice changes from control of centre of mass over a static base, which has been explored in previous lessons, to control of centre of mass over a changing base.
- 12: **'Walking on the wall'**. Various aspects of weight shift in standing, using the wall as support for the forearms and forehead, with emphasis on mobility in the hips and spine. With the head fixed in space on the wall, differentiation of the head and pelvis is explored.
- 13: **'The feet in walking'**. Exploration of the feet in standing and walking, with a focus on contact of the feet with the ground. The attention is continuously being drawn to tactile sensations from the soles of the foot. The movement theme is altering contact with the ground by walking and standing on the outsides, the insides, the heels and the balls of the feet.
- 14: **'Dancing with the wall'**. Two components: explorations of diagonal connections between the foot through the body to the opposite shoulder, and also ipsilateral coordination between arms and legs on each side.

Table 1 (Continued)

- 15: **'Graceful walking'**. A lesson mainly spent walking. Arm swing: both proximal (scapula on ribs) and distal (path of the hand through space) elements are explored.
- 16: **'Driving from the pelvis'**. Mainly revision. The focus is on fine control of the pelvis, and the ability to move it over the base of support in both sitting and standing and walking.

Lessons analysed and coded for themes

The development of codes in qualitative research, for identifying themes or categories in the data, can be either an emergent process that the author identifies during data analysis or may be predetermined from the literature, particularly in content analysis [15]. It may also be a combination of both these approaches, which was the approach used in this study. In this project, the codes were developed from two key sources: in accordance with theoretical concepts gained largely from the literature, but also from the researchers' prior experience of both the Feldenkrais Method and balance retraining classes. Some themes emerged later during the data analysis and interpretation stages supporting the ideas that the researchers already held. This process was documented in the analytical log and reflected on in the personal log. Further refinement of the codes occurred during the review process for publication.

Personal log

A personal log is an integral part of qualitative research methodology [16]. It is considered a source of validation in qualitative research as it contributes to the audit trail, which is the chronological written record of the thoughts, events and decisions of the research process. An extract from the personal log is available on request from the corresponding author. To further strengthen the rigor of the process, an experienced qualitative researcher was consulted (LR).

Definitions for codes

Two major themes were confirmed. One theme related to postural control and the other to motor learning. Most of the data could be coded as being relevant to one or both of these categories.

Motor learning codes

Schmidt and Bjork [17] described some of the fundamental principles of motor learning, such as practice schedules and types of feedback. These concepts have been refined and examined in the ensuing decades, and altered to encompass concepts such as dynamic systems and ecological theory [18]. A review of the literature [18–27] resulted in the development of the motor learning codes as listed in Table 3 (code numbers 1 to 9).

Table 2
Example of lesson transcription with coding (Lesson 9).

Starting position	Movement instructions	Movement task	Motor learning	Postural control
Stand behind chair (6 minutes into lesson)	Bring feet together and shift weight a little to left and right by tilting whole body <i>(keep spine like an iron bar)</i>	Weight shift side to side	Repetition with variability	Practice of control of centre of movement over base of support. Weight shift medio/lateral
	Rest in standing, walk a little		Body awareness of spine	
	Bring feet together and tilt a little forward and backward <i>(notice movement is in the ankles – restrict movement in pelvis this time. Notice pressure under soles of feet)</i>	Weight shift forward/backward	Body awareness of ankles. Body awareness of soles of feet	<i>(Why is the spine rigid in this part of the lesson? Is it to activate more at the ankle – if everything else is constrained, the ankles have to work to maintain balance and produce movement)</i> (ankle strategy)
	Reduce movement to find mid-point	Weight shift with decreasing amplitude	<i>The motor learning is guided not by an external model of what to achieve, but by internal feedback from the soles of the feet (intrinsic feedback)</i>	
	Walk around to rest <i>(we are learning guided by our sensation of satisfaction with how comfortable a movement feels – we are guided by sensation)</i>			
	Imagine you're standing on a clock –12 at toes, 6 at heels, 3 to right, 9 to left. Tilt from 12 o'clock to 6 o'clock <i>(body moving as a board. Feel the pressure under your feet)</i>	Weight shift forward/backward	Use of imagery. Body awareness of soles of feet	Weight shift anterior/posterior
	Tilt a little from 3 to 9 o'clock <i>(moving side to side, tilting like a broom stick. Does not need to be a large movement)</i>	Weight shift side to side	Exploration of 'working space' – still over a static base	Weight shift medio/lateral

Movement instructions column: instructions in **bold**, descriptive/direction of attention instructions in *italics*. Motor learning and postural control columns: *italics* used for comments which later formed part of the analytical log.

Postural control codes

Postural control has been defined as 'the act of maintaining, achieving or restoring a state of balance during any posture or activity' [28, p. 404]. This theme, or category, had two clear subcategories; postural control could be explored in relation to the spatial, or directional, dimensions of control (i.e. where) and also in relation to the body parts, or segments, involved (i.e. how). Both of these subcategories, direction of movement and body part involved, have several properties. Early postural control studies concentrated on activity in the hip and ankle in the maintenance of balance [27], but more recent studies have highlighted the importance of the whole body, including the trunk, head and arms, in postural control [27–32]. Definitions for the postural control codes (as listed in Table 3, code

Table 3
Motor learning and postural control codes.

Motor learning codes	Postural control codes
1. Intrinsic feedback	10. Anterior/posterior stability
2. Extrinsic feedback:	11. Medio/lateral stability
Knowledge of results	12. Rotational stability
Knowledge of performance	13. Ankle strategy
3. Variable practice	14. Hip strategy
4. Amount of practice (repetition)	15. Trunk strategy
5. Whole vs part training (part practice)	16. Step strategy
6. Transfer of learning	17. Head and neck
7. Mental practice	18. Arm and scapula control
8. Exploratory learning	19. Dynamic stability
9. Body awareness/image	

numbers 10 to 19) were developed from the literature [27–32].

Coding of the data

Using these categories, the lesson transcripts were analysed by examining each movement task and coding them according to the motor learning principles and/or postural control tasks present (Table 2).

Analysis of the data

For each Awareness Through Movement lesson, a summary was made of the codes identified, the prominent themes of that lesson, and reflections on the relationship of the material in that lesson to the whole series. These summaries formed an analytical log (Table 4), which is an integral part of the qualitative researcher’s process of integrating large amounts of written information into meaningful themes for idea development and theory building [33].

Intercoder reliability study

The risk of bias is always present in this type of research, as decisions about coding are frequently subjective in nature. One form of bias is the interpretation of the researcher [16]. The first author (KC) is a Feldenkrais practitioner. To determine whether the codes had been applied accurately to the data, intercoder reliability was assessed. Intercoder reliability testing is a common feature of content analysis, and is one method of establishing rigor in the data analysis [16]. To assess the reliability of the coding process, a sample of the data was coded independently by an experienced physiotherapist (CS) who had specialised knowledge of gait and

Table 4
Extracts from analytical log.

Lesson 1
...The ability to control movements of the pelvis, fundamental for balance in standing, is commenced. ... Rotation is an important element of walking, and the ability to turn the upper body on the pelvis is integral for balance stability in standing and moving. By introducing pelvic rotation in sitting, the relationship to the chair helps to clarify the movements of the pelvis. The chair also helps to keep the pelvis still in some movements, to explore movement of the upper body in relation to the lower body – which would be a more difficult exploration in standing.
Lesson 8
Another interesting idea that comes from the lessons is the relationship between trunk control/flexibility and the magnitude of postural sway – can the magnitude of the postural sway be decreased by gaining finer control of the postural muscles in the trunk, and also by improving mobility of the ribs and ankles to allow these fine movements to take place?

balance disorders (including a PhD in this area) and was not a Feldenkrais practitioner. Three sections of lessons, each about 15 minutes in duration, were selected from three different lessons for this purpose.

There was good agreement between coders for both the motor learning codes [$\kappa=0.63$, 95% confidence interval (CI) 0.50 to 0.76] and the postural control codes ($\kappa=0.69$; 95% CI 0.49 to 0.89) [34, p. 404], suggesting that an independent coder had a reasonable level of agreement with elements identified as motor learning and postural control in the data.

As well as achieving good intercoder reliability, this process also validated the codes. The coder who was not trained in the Feldenkrais Method was able to identify elements of motor learning and postural control training in the lessons with much the same frequency and distribution as a per-

Table 5
Frequency of motor learning and postural control codes in each Awareness Through Movement lesson.

Lesson	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1. Intrinsic feedback	18	27	12	12	12	8	6	9	8	9	14	8	10	9	11	7	180
2A. Extrinsic feedback: KR	7	4	3	4	2	1	2	1	1	2	3	1	1	4	1	2	40
2B. Extrinsic feedback: KP																	0
3. Variable practice	15	28	15	10	9	11	13	9	14	6	7	19	6	8	17	20	207
4. Repetition	15	28	15	10	9	11	13	9	14	6	7	19	6	8	17	20	207
5. Part practice	2	4		7			4			4	6				3	3	33
6. Transfer of learning		2	1														3
7. Mental practice/imagery				2	5	1		1	2	1	1					1	14
8. Exploratory learning	3	8	3		1	1		4	9	7	4	4	7	9	7	7	74
9. Body awareness/image	15	20	10	13	12	8	4	9	6	9	7	8	10	13	11	8	86
10. Anterior/posterior stability	1	13	15	16		13	8	12	14	10	11		1	4	1	9	128
11. Medio/lateral stability	6	19	1	3	1	14	14	13	14	1	11	2		11	1	12	123
12. Rotational stability	15	8	7	4		6				3				3		6	52
13. Ankle strategy				1	12	4	1		14		8	7	6	5	3		61
14. Hip/pelvis strategy				1		8	8	7	10		4	18		1		1	58
15. Trunk strategy	2	17	11	4			3	4		7				1		6	55
16. Step strategy				1							4		1	11			17
17. Head and neck	4	8		1				2					1	3		5	24
18. Arm and scapula control				3						2						13	15
19. Dynamic stability	1	3	3	5	6	5	2	3	3	4	14	5	20	8	19	3	104

KR, knowledge of results; KP, knowledge of performance.

Table 6
Results of content analysis of Feldenkrais Method balance lessons.

Theme and categories	Example/quote	Comment
1. Motor learning theme: intrinsic feedback	Weight from side to side in standing: <i>'How do you do this? What does your head do? Where does the pelvis go? ... Does the pelvis move in the same direction as the head?'</i> (Lesson 4)	Proprioceptive feedback from spine, ankles, knees and hips
1.1 Proprioception		
1.2 Tactile feedback	<i>'What can you feel through the soles of the feet? ... How much is in contact with the ground? Imagine you're standing on sand – what would your foot prints look like – would the left and right look the same? Is one deeper or broader than the other?'</i> (Lesson 2)	Tactile feedback from soles of the feet
1.3 Quality of movement	<i>'As you walk, pay attention to ankles – do they feel stiff or tight? How are they when you put your foot on the ground?'</i> (Lesson 5) <i>'Sense how easy this is. ... How much effort is it?'</i> (Lesson 10)	Quality of movement – ease/effort. These observations allowed the participants to gain information not only on what they were doing, but how they were doing a task
2. Motor learning theme: extrinsic feedback	In some lessons, reference was made to external landmarks: <i>'Notice the exact spot on the wall which you are looking at when you turn your head to the left.'</i> (Lesson 1)	Generally used at the start and end of each lesson to evaluate the effects of the lesson
2.1 Knowledge of results	Other lessons used the ability to perform a specific task, such as standing on one leg (Lesson 11) or rising from a chair (Lesson 10), to assess the effects of the lesson	
2.2 Knowledge of performance	Not used	Individual feedback to participants on their performance was not given
3. Motor learning theme: variable practice	<i>'Stand with your feet parallel, about 10 cm apart. Soften the right knee and lift the right heel and repeat many times, with weight on left leg all the time. ... Repeat with other leg ...'</i> (Lesson 11)	This strategy was used frequently when introducing a new movement task or sequence of movements
3.1 Variable practice: performing the movement task with one side of the body, and then repeating these movements on the other side		
3.2 Variable practice: freezing and unfreezing degrees of freedom	In Lesson 1, in sitting, the participants 'froze' the pelvis in a backward rotated position, and then explored thoracic and cervical movement with the pelvis held still. The pelvis was then 'unfrozen' and pelvic rotation was combined with the thoracic and cervical components	This strategy was used to isolate movements in specific areas of the body to concentrate on improving movement control in that area (see example 1, Lesson 1, where lumbar movement was 'frozen' to concentrate on thoracic movement instead). At other times, it was used to explore a non-habitual movement (see example 2, Lesson 9)
	In Lesson 9, Participants alternated between lateral weight shift with their spine 'frozen' (so that the head moved through space during weight shift) and the spine 'unfrozen' (so that the head stayed fixed in space during weight shift as the pelvis moved, but the spine was flexible and allowed the head to stay still)	
3.3 Variable practice: use of 'constraints' to alter the movement pattern	<i>'Round the back and tilt the pelvis backward and the weight goes backward on sit bones. Arch the back and the stomach comes forward, and the pelvis tilts forward; you might look up a little. We are now going to continue arching and rounding the back with a constraint. The constraint – lean your forearms on your knees, the hands can hang or be interlinked. Arch and round back in this position, you can involve the head looking up and down a little.'</i> (Lesson 10)	This constraint alters the body mechanics to produce flexion and extension through the whole spine, not just the lumbar spine during the pelvic tilt. The purposeful use of constraints in the Feldenkrais Method to shape the dynamics of postural coordination is demonstrated here. The concept is strongly linked to that of exploratory learning, and is understood as an integral strategy to introducing non-habitual movements
3.4 Variable practice: variations of movement patterns during an activity	Three variations of walking: <i>'Lift the heels so the weight goes onto the balls of the feet ... walk on the balls of the feet ... Grab the floor with your toes and now walk a little. ... Lift your toes up off the floor, and now walk a little like this. ...'</i> (Lesson 13)	These types of variability allowed the participants to explore non-habitual ways of moving, and also to practice movement tasks with many subtle internal perturbations to their balance

Table 6 (Continued)

Theme and categories	Example/quote	Comment
3.5 Variable practice: exploration of different sequences of movement	Lesson 1 involved the task of turning whilst sitting. The turning was initiated by the eyes, the shoulders and the knees at different stages of the lesson	This variation allowed participants to explore moving in non-habitual ways
3.6 Variable practice: variation of the speed	Movement speed varied from very slow to fast	Fast movements tended to be used towards the end of each lesson
3.7 Variable practice: amplitude of movement	At times, the movement was exaggerated. At other times, the amplitude was made very small: <i>'Shift your weight to the outside of your feet just a little, barely enough for someone to be able to observe it.'</i> (Lesson 13)	Variation of the amplitude of movements demanded complex intersegmental control
4. Motor learning theme: amount of practice (repetition)	The instructions: <i>'Repeat this movement several times'</i> and <i>'Repeat this movement many times'</i> were given in each lesson. Each movement was practised 10 to 20 times and then a new variation was added (as described above), which was again practised many times. There was an average of 13 variations per lesson, so the whole movement task was generally practised hundreds of times each lesson	Repetition was used for every task in every lesson. The actual number of repetitions each person performed was unable to be determined, as this varied with each individual. Only the instruction <i>'Repeat this movement'</i> could be coded from the transcripts, but not the response to this instruction
5. Motor learning theme: whole vs part training (part practice)	In Lesson 11, the participants practised swinging and placing one leg repeatedly, then practised swinging and placing the other leg and then progressed to combining these movements into walking. Forward movement of the trunk (in combination with reaching the arm forward) was practised in sitting in Lesson 4. This forward lean movement in sitting, combined with arm reach, was then integrated into a sit-to-stand task	Part practice was used in most lessons. A certain part of the movement task was practised and then integrated back into the whole
6. Motor learning theme: transfer of learning	All the learning took place inside a carpeted room, and was not integrated into other environments or practised on other surfaces.	Transfer of learning from one environment to another was not used explicitly in the classes, although the relevance of what was being taught to <i>'real-life'</i> situations was discussed at times
7. Motor learning theme: mental practice	<i>'If you don't feel ready to cross the right foot in front of the left, just stand there, holding the back of your chair and imagine yourself doing this movement. How would your weight shift before you lifted the right leg? How would the pelvis move? What would your left leg do to get ready to accept your weight? What would happen in the left hip? In the left knee? In the left ankle? Perhaps after crossing and uncrossing the right leg a few times in your imagination, you might be ready to try it.'</i> (Lesson 12)	Here mental practice is being used to build confidence and understanding of the movements involved in a particular sequence prior to attempting a difficult task
8. Motor learning theme: exploratory learning	<i>'Imagine you are doing that alternating movement of lifting the heels then the balls of the feet. . . . Make it easy and graceful in your imagination. . . . Now do it for real.'</i> (Lesson 6)	In this example, mental practice is being used to refine a skill
	<i>'What is your head doing as you move your weight from side to side, does it move too, or is it still? What is your pelvis doing? Is your body rigid? Is there any movement in your hip joints? Are your knees locked or are they soft? Do you notice the pressure change under the soles of your feet?'</i> (Lesson 2)	Each movement sequence was performed as an exploration. Each repetition was a search for new information. The instructor guided the participants with each repetition to pay attention to feedback from different parts of the body, to learn how he or she was performing that movement.
9. Motor learning theme: body awareness	Open-ended language was used by the instructor (highlighted in bold): 'Discover how your balance is today. . . . Explore the same on the left side Notice the quality of the movement . . . Notice what happens in the ankle, the knee, the pelvis. Is there a tendency to turn to the right? How does the ankle accommodate this movement?' (Lesson 14)	The participants are guided towards making discoveries about themselves and their movement organisation, and the language which was used reflected this
	Lesson 5 (in sitting): <i>' . . . Pay attention to what happens in the ankle – feel how it opens in the front. Feel what happens in the right knee and in the right hip joint. Can you feel an echo in the left hip joint? Let the leg relax each time you put it down. Which muscles are you working? Is it your calf?'</i>	The participants were asked to pay attention to very small movements, and also to pay attention to specific body areas, by trying to identify where the sense of effort was being felt
	<i>'Pay attention to the touch of the foot on the ground. . . . Pay attention to the touch of the foot on the floor as the pressure changes. . . . Pay attention to the contact of the foot on the ground. . . . Feel the contact of the ball of the foot on the floor. . . . Compare the contact of the right foot on the ground compared to the left Pay attention to the contact of the feet on the ground Walk – feel the pressure travel along the sole of the foot.'</i> (Lesson 5)	Areas of the body particularly involved with balance, such as the feet, the pelvis and the spine, were given considerable attention during the lessons, as illustrated by this example concerned with the foot

Table 6 (Continued)

Theme and categories	Example/quote	Comment
10. Postural control themes: medio/lateral stability	<p>Most lessons started with practising side-to-side weight shift: <i>'Shift your weight to the right and back Shift your weight to the left and back. Now shift your weight to the left and the right.'</i> (Lesson 1)</p> <p>Control of lateral weight shift was explored using the pelvis to initiate the movement: <i>'Cross the left foot in front of the right one. Transfer your weight from left to right, using the pelvis and keeping the head quiet. Feel how the spine participates in this movement.'</i> (Lesson 8)</p> <p>Weight shift was also initiated by the head: <i>'Bring your feet together and shift your weight a little to left and right by tilting whole body leading with your head – keep your spine like an iron bar.'</i> (Lesson 9)</p>	<p>Movement over the centre of mass in the coronal plane was explored in almost every lesson</p> <p>Explorations of weight shift in these varied directions could also be considered as explorations of the limits of stability. The participants were practising moving their centre of mass over their base of support</p> <p>This variation emphasises control of weight shift by the ankle musculature, whereas weight shift in the above example (Lesson 8) demands more activity in the spinal musculature if the head is to be kept still</p>
11. Postural control themes: anterior/posterior stability	<p>Movements in this direction were also introduced in the first lesson, then explored in Lesson 3 in sitting, in Lesson 5 during sit-to-stand preparation and then in most of the lessons in standing and walking</p>	<p>Movements of the centre of mass in the sagittal and coronal planes were often combined into diagonal and circular directions (e.g. moving the pelvis in a 'figure of eight') with the feet in various positions</p>
12. Postural control themes: rotational stability	<p>The very first lesson was an exploration of rotation in sitting, but no other lesson was mainly focused on the movement of rotation or turning. In later lessons, where participants were practising stepping and walking with active involvement of the pelvis, rotation in the trunk occurred to allow counter-rotation to occur between the pelvis and the head</p>	<p>Intersegmental rotation was therefore practised, but there were not many movement tasks involving turning in space around a vertical axis</p>
13. Postural control themes: ankle control	<p>Three lessons specifically addressed ankle activation – Lesson 5 in sitting, Lesson 9 in standing and Lesson 13 in walking. In every other lesson (apart from the first three lessons in sitting), the ankles were involved in most movement tasks; the lessons were all performed in standing and involved postural adjustments over varied bases of support. Another strategy to involve activation of the feet and ankles was that the participants did not wear shoes during the classes</p>	<p>Bare feet (or socks) was unusual for many of the participants, and helped to focus their attention on their feet</p>
14. Postural control themes: intersegmental control of the pelvis and trunk	<p>Movement tasks involving the pelvis and trunk were present in every lesson except the lesson on ankle mobility in sitting (Lesson 5). The first three lessons in sitting concentrated on trunk flexibility and control in each of the cardinal planes, by integrating pelvic and head movements through the spine. Lesson 1 involved rotation, Lesson 2 concentrated on lateral flexion and Lesson 3 was about flexion and extension. Once the lessons progressed to standing, from Lesson 6 onwards, every lesson was concerned with hip and trunk strategies for balancing in standing and walking. Lesson 7: <i>'Stand with your feet parallel and transfer weight from side to side by moving the pelvis, keeping the head quiet in the middle. Now make circle with pelvis, . . . a small and clear circle. Feel how the rest of you responds – ribs, knees, ankles.'</i></p>	<p>This postural control strategy of improving intersegmental control between the pelvis and head, through improved flexibility and movement control in the spine, was one of the key features identified in this analysis of the content of these classes</p>
15. Postural control themes: step strategy	<p>There was one lesson where the participants practised slowly shifting their weight forward on one foot (and simultaneously 'unloading weight on the other') until a point was reached when the 'unsupported' leg automatically swung forward into place just in time to receive the weight of the body (Lesson 11)</p>	<p>The participants were never instructed to place themselves in a situation where they needed to 'save' themselves with a step strategy</p>
16. Postural control themes: head and neck	<p>In several classes, participants engaged in movement tasks involving the differentiating head and neck movements from the trunk such as in Lesson 1 (in sitting): <i>'Move the right knee forward and turn your body to the left, but keep your face turned to front.'</i></p> <p>In other classes, the integration of head and neck movements into trunk movements was practised, as in Lesson 2: <i>'Put your right hand on top of your head. Shift your weight to the left hip bone and the right sit bone raises and the head bends to the right.'</i></p>	<p>The ability to move the head and neck independently from the trunk was explored and developed, particularly in the first few lessons in sitting. This concept was revisited in a few later lessons when the participants were engaged in more dynamic tasks</p>

Table 6 (Continued)

Theme and categories	Example/quote	Comment
17. Postural control themes: arm and scapula control	<p>The relationship of the arms to postural control was explored during sit to stand (Lessons 4 and 10) and more extensively in Lesson 15. Most of this lesson was spent walking around the room practising variations of arm swing and awareness of the role of the shoulder girdle during walking</p> <p>Attention was drawn to the movement of the shoulder girdle during walking. For example, the participants were asked to pay attention to the stance phase (Lesson 15): ‘During this process the foot is going backwards under the body. Notice what happens to the shoulder on the right – can you feel how it moves forward, as the right foot moves backward relative to the body?’</p> <p>There were also variations in this lesson involving increased arm swing and decreased arm swing, such as ‘Walk with the right arm stuck to the side, and notice what this does to your walking. Notice how you lose power in the walking.’</p>	<p>These movement tasks involving the arm and shoulder girdle appeared to serve two purposes. Firstly, activities were practised that increased the differentiation between the scapula and the rib cage, to improve the ability of the scapula to move independently of the trunk. Secondly, arm movements were used as internal perturbations, as a challenge to balance during dynamic tasks</p> <p>No specific walking programme (such as outdoor walking) was included in the classes</p>
17. Postural control themes: dynamic stability	<p>All lessons involved at least one task involving dynamic stability, but this was generally a minor component of the lesson. Several later classes explored moving through space (Lessons 11, 13 and 15). The participants practised walking around the room, altering variables such as arm swing, speed or step width. For example, in Lesson 13, the participants were instructed to walk in challenging ways such as ‘Walk on your heels.Walk on the balls of your feet Grab the floor with your toes and walk a little like this’</p>	<p>Overall, there was relatively little time spent in each lesson on activities which involved dynamic stability; most movement tasks had a static base of support</p>

son trained in the Feldenkrais Method. This suggests that the codes were sufficiently described and differentiated to be applicable for this purpose.

Results

The frequency of language describing motor learning strategies and postural control retraining strategies identified in the transcripts of the Awareness Through Movement lessons is presented in Table 5. A description of the analysis of the data and the results is provided in Table 6. All of the codes were used throughout the lessons with the exception of extrinsic feedback (knowledge of performance), transfer of learning to different environments and step strategy (defined as a rapid step to realign the centre of mass over the base of support). The latter was principally found in just one lesson (Lesson 11) which involved a particular type of stepping practice. The motor learning principles of variability of practice, repetition, intrinsic feedback and exploratory learning were highly utilised in all lessons. Postural control elements of controlled movements of the centre of mass in different directions utilising varying bases of support and intersegmental control were found in all lessons. Dynamic stability tasks were found to a greater extent in the later lessons than the early lessons.

One of the key findings was the frequency of tasks focused on improving the role of the trunk in postural control. Both

trunk flexibility and selective control of the trunk to improve intersegmental control of the pelvis, spine and head were addressed in most lessons. Another key finding was the central role of intrinsic feedback as a motor learning strategy, and that this strategy was closely linked to the concepts of body awareness and exploratory learning.

Discussion

These results confirmed that the content of the lessons first devised by Dr Feldenkrais over 30 years ago are consistent with modern-day motor learning principles and postural control theories. Indeed, the recent systematic review and meta-analysis by Sherrington *et al.* [2] found that the most effective exercises for prevention of falls involved ‘exercises conducted while in standing in which people aimed to stand with their feet closer together or on one leg, minimize the use of hands to assist and practice controlled movements of the centre of mass and did not include a walking program’ (p. 2234). This could be a description of many of the Awareness Through Movement lessons examined in this study. In fact, some of Dr Feldenkrais’ ideas, such as exploratory learning, use of constraints, use of imagery and variability of practice, are still acknowledged as useful components of motor skill learning programmes, but are not well integrated into many mainstream balance programmes [35,36]. The way in which a few of these key features were integrated into the lessons is discussed below.

Exploratory learning

Participants were not taught specific strategies to improve their balance, but were presented with many opportunities for learning and allowed to work out solutions for themselves; this is exploratory learning. Karl Newell's description of exploratory learning as a search for new attractor regions [21] is congruent with the Feldenkrais Method approach. Dr Feldenkrais recognised these attractor regions in movement (he called them 'habits') which 'can be likened to a groove into which the person sinks never to leave unless some special force makes him do so. With time, the groove deepens, and stronger forces are necessary to remove him from it' [37, p. 118].

Many of the strategies that Dr Feldenkrais used in Awareness Through Movement lessons were concerned with this concept of moving people out of their established movement habits. These strategies included the use of novel movements, constraints and variations to movement tasks, such as reversing the direction or movement sequence of familiar movements. These strategies could be considered 'perturbations' [38]; a perturbation is what causes behaviour to move out of a stable pattern into a period of instability, and then into a new pattern. This new solution could be considered a new attractor region, representing new movement solutions to balance problems. For example, instead of habitually taking a step to regain balance if experiencing a perturbation, a person may learn to make an adjustment with their pelvis and trunk to maintain the centre of mass within their current base of support. This style of learning results in movement solutions that are flexible and which can be transferred from one situation to another. This type of exploratory learning represents an approach which may be useful in balance retraining.

Head, arms and trunk control

The approach to the trunk area used in the Awareness Through Movement lessons is quite different to that in standard balance training classes [35,39,40]. The goal of many movement tasks in the Awareness Through Movement lessons was to improve the range and selective control in the trunk musculature. Due to the complexity of controlling a high centre of mass over a small base of support in bipedal gait, control of the head, arms and trunk is crucial to successful balance [41]. Dr Feldenkrais observed, from his martial arts experience, that 'It is the thorax which connects the source of power, the pelvis, with our head, the source of orientation and intentional movement' [37, p. 78]. The assumption by Dr Feldenkrais that many people, especially as they age, do not move well in the trunk is consistent with recent findings showing that older adults lose trunk flexibility. Decreased flexibility in the trunk limits the ability of the trunk to make postural adjustments, and impacts negatively on balance [30,31].

Movement of the pelvis independently from the chest, rather than the whole trunk moving as a rigid entity [31], was developed in several lessons, as the participants learnt to make subtle movements of the pelvis to control their balance. They also learnt about the role of the spine to enable the head to remain steady in space, while the pelvis moved independently to maintain balance. The ability to keep the head steady has been identified by Patla [41] as a key component of successful balance due to the importance of the head for 'optimizing both the labyrinth role in controlling balance and possibly the requirements of vision as well' (p. 176). This 'uncoupling' of the head and the pelvis is a major theme through the Feldenkrais Method lessons, and may contribute to improved balance performance.

Although there was some use of 'knowledge of results' in each lesson, the other type of extrinsic feedback, 'knowledge of performance', was a notable omission. It was the most prominent motor learning strategy not found in the lessons which has been described in the literature [17,18,20,21,27]. There was minimal feedback to participants during a lesson about how they were performing a task. The lack of extrinsic feedback is a deliberate strategy in the Feldenkrais Method approach, linked to the concept of exploratory learning. Just as the instructor does not demonstrate a movement task in the Feldenkrais Method, as this is considered to detract from the participant's experience of discovering how to do the movement for himself/herself, neither does the instructor 'correct' a participant. If a participant is struggling with a movement sequence, rather than giving extrinsic feedback designed to 'improve' the participants' movement, the instructor will alter the instructions to include different ways to approach the movement task, so the participant finds a solution himself, through his/her own guided explorations.

This process of refining instructions to guide the participant's explorations is consistent with Newell's concept of 'transitional feedback' [21, p. 232]. This type of feedback guides a learner towards improving a movement task by offering suggestions on ways to practice the movement, without practice attempts being classed as right or wrong. Although these types of instructions were given in the Feldenkrais Awareness Through Movement lessons, coding did not distinguish between the primary instruction for a movement task and secondary or refining instructions, so transitional feedback was not identified.

Another aspect to the Feldenkrais Method, related to the lack of extrinsic feedback about knowledge of results, is the use of 'hidden' rather than 'transparent' goals in a lesson. The practitioner was aware of the purpose of specific movement tasks, but this was not necessarily communicated to the participants. As discussed above, the participants were involved in exploratory learning, where the process of movement discovery, and expansion of the movement repertoire, is considered more important than completing a movement task in a specified way.

Variability of practice as a motor learning strategy was used extensively in the lessons. The content analysis identified seven different strategies for introducing variability into the movement tasks (unilateral movements, freezing and unfreezing degrees of movement, use of 'constraints', variation of movement patterns, variations in movement sequencing, variations in speed and amplitude) as described in Table 6. Variability of practice has been found to lead to improved outcomes compared with multiple repetitions of the same task; although it may take longer to learn a task, the retention of the learning will be improved [23]. Each variation demands slightly different neuromuscular organisation and exploration of the perceptual–motor workspace. A repertoire of movements is built in such a way that the body does not have a single response to a situation, but multiple options to draw on [42]. Other balance training approaches may find some of these strategies useful to incorporate into their own programmes to expand the variability of their exercises.

There was little practice of dynamic stability tasks, except in a few of the later lessons. As many falls occur in the context of higher level postural control tasks, such as walking, turning and negotiating obstacles [43], the participants may have gained more improvement in postural control if they had had the opportunity to practice some of these more complex tasks in the lessons.

Content analysis for examination of balance retraining classes has not been documented previously in the literature. This innovative study has provided a framework to examine one approach to balance retraining. Future studies applying this style of examination to other approaches, such as Tai Chi or Otago balance classes, could identify specific postural control and motor skill acquisition strategies unique to these approaches. This information would be beneficial to all practitioners designing classes for balance retraining.

Limitations of the study

The results obtained in this study relate to a particular series of recorded Feldenkrais Awareness Through Movement lessons (Getting Grounded Gracefully), delivered by a particular Feldenkrais practitioner. Different Feldenkrais Awareness Through Movement lessons aimed at improving balance may have quite different content, and even the same lessons delivered by a different practitioner may be slightly different as different practitioners will emphasise different elements within the series of movement sequences. Caution must be taken when generalising these results to other Feldenkrais Awareness Through Movement lessons.

Another limitation of this study was that the data analysed were audio recordings of the instructions given to participants rather than the actual activities of the participants. There was an assumption made that the participants were moving in certain ways. To verify if the participants

were actually doing the tasks that they were instructed to do, an analysis of a video recording of the lessons would need to be undertaken. A video analysis of class participants may provide valuable information about activities undertaken in Feldenkrais Awareness Through Movement lessons for balance retraining. This approach to understanding balance retraining would also be of interest with approaches such as Tai Chi and Otago balance classes [35].

Although Table 3 presents information on the frequency with which codes were represented in the data, this information is somewhat simplified. Each code was counted as being present or absent in each movement task within the lessons, but the relative amount of time spent on the various motor learning strategies and postural control tasks was not measured. The frequency count therefore gives a general indication of what was happening in the lessons, but cannot be interpreted as a definitive account of the time spent on each aspect. Also, only explicit instructions were coded; therefore, more subtle but important elements in the lessons may have been missed.

Although the inter-rater reliability study showed good results, there was some disagreement between raters. Discussion between the raters (after completion of the coding) revealed that part of the decision-making in coding involved deciding on the relative contribution of the various codes in any movement task. In some tasks, a code was obviously present or not, but in other tasks, it was a matter of whether there was sufficient involvement of a particular code to be counted. For example, activity of the musculature around the ankle is present in any activity in standing, but when is a movement task deemed to be specifically involving the ankles? Tighter descriptions of how to code may have resulted in higher inter-rater reliability.

Another consideration is the choice of methodological approach. In choosing a content analysis approach, this meant that the authors worked within existing theories. It is possible that the use of an alternative qualitative research approach, such as grounded theory [16], may have allowed the development of a different theoretical model and provided new insights into the Feldenkrais Method.

Concluding comments

This study validates ongoing research into the Feldenkrais Method. It has provided a rationale for the Feldenkrais Awareness Through Movement lessons as an effective approach based on sound theoretical principles. It appears that the Feldenkrais Awareness Through Movement lessons fit well within motor skill learning theories, particularly the dynamic systems theory. These lessons involve tasks dealing with many different aspects of balance, including some that are not usually addressed in typical balance classes, but which may be beneficial for all clients attempting to improve their balance. Furthermore, this study has provided a model

of investigation into balance retraining that may be useful for future researchers in this field.

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References

- [1] Gillespie L, Gillespie W, Robertson M, Lamb S, Cumming R, Rowe B. Interventions for preventing falls in elderly people. *Cochrane Database Syst Rev* 2003;4:CD000340.
- [2] Sherrington C, Whitney J, Lord S, Herbert R, Cumming R, Close J. Effective exercise for prevention of falls: a systematic review and meta-analysis. *J Am Geriatr Soc* 2008;56:2234–43.
- [3] Feldenkrais M. *Awareness Through Movement: health exercises for personal growth*. London: Arkana; 1990.
- [4] Stephens JL, Davidson J, De Rosa J, Kriz M, Saltzman N. Lengthening the hamstring muscles without stretching using 'Awareness Through Movement'. *Phys Ther* 2006;86:1641–50.
- [5] Feldenkrais M, editor. *The Feldenkrais Method. Awareness Through Movement Lessons*. Paris: International Feldenkrais Federation; 1995.
- [6] Connors KA. An investigation into Feldenkrais Method movement classes and their effect on balance in older adults. Melbourne: University of Melbourne; 2008. p. 188.
- [7] Hall S. Study of the effects of various forms of exercise on balance in older women. In: Stephens J, editor. *Research studies*. USA: Feldenkrais Educational Foundation of North America in Portland, Oregon; 2001.
- [8] Vrantsidis F, Hill KD, Moore K, Webb R, Hunt S, Dowson L. Getting Grounded Gracefully: effectiveness and acceptability of Feldenkrais in improving balance. *J Aging Phys Activ* 2009;17(1): 57–76.
- [9] Stephens J, Pendergast C, Roller B, Weiskittel R. Learning to improve mobility and quality of life in a well elderly population: the benefits of Awareness Through Movement. *Feldenkrais Res J* 2005;2: 1–17.
- [10] Batson G, Deutsch J. Effects of Feldenkrais Awareness Through Movement on balance in adults with chronic neurological deficits following stroke: a preliminary study. *Complement Health Pract Rev* 2005;10:203–10.
- [11] Connors KA, Galea M, Said CM. Feldenkrais Method balance classes improve balance in older adults: a controlled trial. *Evid Based Complement Alternat Med* 2009 [advance access 24.06.09], doi:10.1093/ecam/nep055.
- [12] Stephens J, DuShuttle D, Hatcher C, Shmunis J, Slaninka C. Use of Awareness Through Movement improves balance and balance confidence in people with multiple sclerosis: a randomized controlled study. *Neurol Rep* 2001;25:39–49.
- [13] Mayring P. Qualitative content analysis. In: Flick U, editor. *A companion to qualitative research*. London: Sage Publications; 2004.
- [14] Webb R. *Getting Grounded Gracefully CD series*. Feldenkrais Connections, Lower Templestowe, Melbourne; 2005. Available at: www.gettinggroundedgracefully.com.au. Website last accessed 11/12/2009.
- [15] Krippendorff K. *Content analysis: an introduction to its methodology*. Thousand Oaks, California: Sage Publications; 2004.
- [16] Silverman D. *Interpreting qualitative data*. 3rd ed. London: Sage Publications; 2006.
- [17] Schmidt R, Bjork R. New conceptualizations of practice: common principles in three paradigms suggest new concepts for training. *Psychol Sci* 1992;3:207–16.
- [18] Newell KM. Change in movement and skill: learning, retention and transfer. In: Latash M, Turvey M, editors. *Dexterity and its development*. Mahwah, New Jersey: Lawrence Erlbaum Associates; 1996. p. 393–430.
- [19] Higgins S. Motor skill acquisition. *Phys Ther* 1991;71:117–23.
- [20] Laguna PL. Comparison of sources of task-related information during motor skill acquisition and performance of a complex motor task. *J Hum Move Stud* 2004;47:155–81.
- [21] Newell KM. Motor skill acquisition. *Ann Rev Psychol* 1991;42:213–37.
- [22] Overdorf V, Schweighardt R, Page SJ, McGrath RE. Mental and physical practice schedules in acquisition and retention of novel timing skills. *Percept Motor Skills* 2004;99:51–62.
- [23] Krakauer J. Motor learning: its relevance to stroke recovery and neurorehabilitation. *Curr Opin Neurol* 2006;19:84–90.
- [24] Van Vliet P, Wulf G. Extrinsic feedback for motor learning: what is the evidence? *Disabil Rehabil* 2006;28:831–40.
- [25] Van Dijk H, Jannick M, Hermens H. The effect of augmented feedback on motor function of the affected upper extremity in rehabilitation patients: a systematic review of randomised controlled trials. *J Rehabil Med* 2005;37:202–11.
- [26] Mulder T. Motor imagery and action observation: cognitive tools for rehabilitation. *J Neur Transmiss* 2007;114:1265–78.
- [27] Shumway-Cook A. *Motor control: translating research into clinical practice*. Philadelphia, PA: Lippincott Williams and Wilkins; 2007.
- [28] Pollock A, Durward B, Rowe P, Paul J. What is balance? *Clin Rehabil* 2000;14:402–6.
- [29] Blackburn J, Riemann B, Myers J, Lephart S. Kinematic analysis of the hip and trunk during bilateral stance on firm, foam and multiaxial support surfaces. *Clin Biomech* 2003;18:655–61.
- [30] Gruneberg C, Bloem B, Honegger F, Allum J. The influence of artificially increased hip and trunk stiffness on balance control in man. *Exp Brain Res* 2004;157:472–85.
- [31] Paquette C, Paquet N, Fung J. Aging affects coordination of rapid head motions with trunk and pelvis movements during standing and walking. *Gait Posture* 2006;24:62–9.
- [32] Carpenter M, Adkin A, Brawley L, Frank J. Postural, physiological and psychological reactions to challenging balance: does age make a difference? *Age Ageing* 2006;35:289–303.
- [33] Richards L. *Handling qualitative data: a practical guide*. London: Sage Publications; 2005.
- [34] Altman D. *Practical statistics for medical research*. London: Chapman and Hall; 1991.
- [35] Gardner M, Buchner D, Robertson C, Campbell J. Practical implementation of an exercise-based falls prevention programme. *Age Ageing* 2001;30:77–83.
- [36] Bella M. Mobility training for the older adult. *Top Geriatr Rehabil* 2003;19:191–8.
- [37] Feldenkrais M. *Body and mature behaviour: a study of anxiety, sex, gravitation and learning*. Madison, CT: International Universities Press (original work published 1949); 1996.
- [38] Buchanan P, Ulrich B. *The Feldenkrais Method: a dynamic approach to changing motor behavior*. *Res Quart Exerc Sport* 2001;72: 315–23.
- [39] Newton S. *Sample class: B.A.S.E. training*. IDEA Fitness J 2005:99–100.
- [40] Nnodim J, Strasburg D, Nabozny M, Nyquist L, Galecki A, Chen S, et al. Dynamic balance and stepping versus Tai Chi training to

- improve balance and stepping in at-risk older adults. *J Am Geriatr Soc* 2006;54:1825–31.
- [41] Patla A. *Adaptability of human gait: implications for the control of locomotion*. Amsterdam: Elsevier; 1991.
- [42] Van Vliet P, Heneghan N. Motor control and the management of musculoskeletal dysfunction. *Man Ther* 2006;11:208–13.
- [43] Shkuratova N, Morris M, Huxham F. Effects of age on balance control during walking. *Arch Phys Med Rehabil* 2004;85:582–8.

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