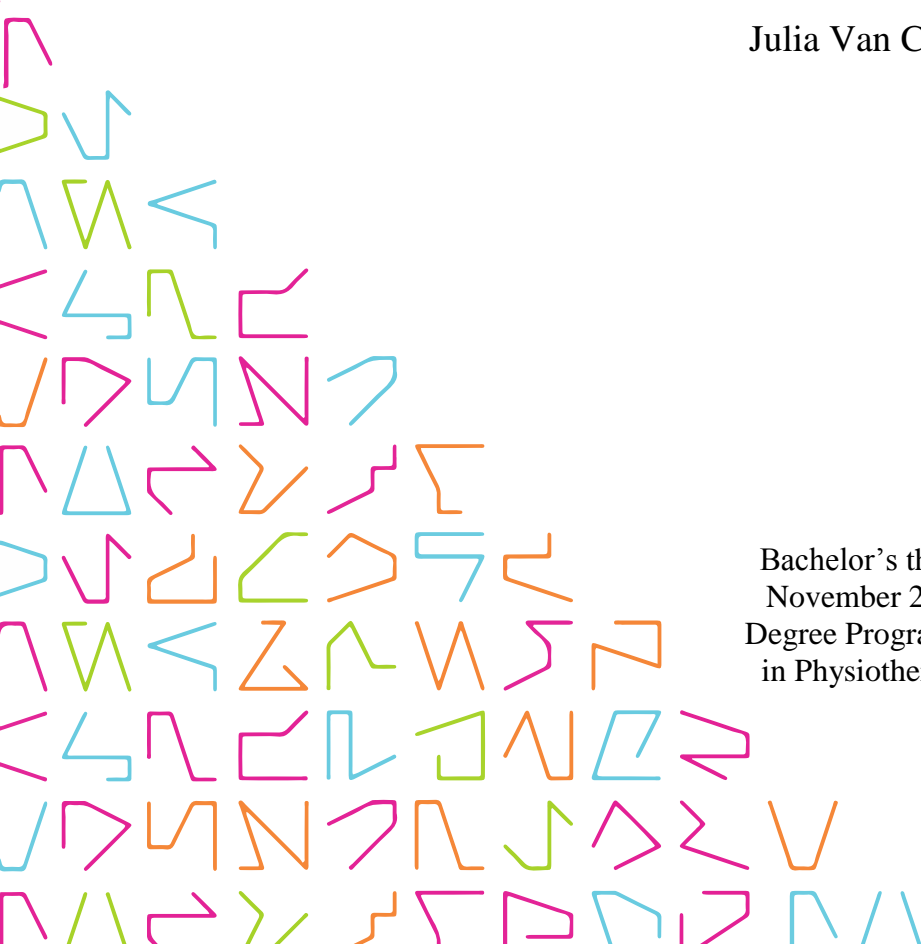


**A RATIONALE FOR A BALLET  
EXERCISE-BASED BALANCE  
TRAINING PROGRAMME FOR  
OLDER ADULTS WITH BALANCE  
IMPAIRMENTS**

An Alternative Approach to a Group-  
Based Balance Training in Physiotherapy

Julia Van Camp

Bachelor's thesis  
November 2015  
Degree Programme  
in Physiotherapy



## **ABSTRACT**

Tampereen ammattikorkeakoulu  
Tampere University of Applied Sciences  
Degree Programme in Physiotherapy

**JULIA VAN CAMP:**

A Rationale for a Ballet Exercise-Based Balance Training Programme for Older Adults with Balance Impairments

An Alternative Approach to a Group- Based Balance Training in Physiotherapy

Bachelor's thesis 66 pages

August 2015

---

The objective of this study was to combine ballet exercise and its teaching principles with physiotherapy practice for improving balance in elderly patients with balance impairment. The purpose of this study was to create theoretical and practical grounds for a balance training programme for older adults comprising ballet exercises. The study resulted in materials for a balance training programme grounded in the current literature on balance control, physiological changes in balance control associated with aging, the principles of exercise and strategies of balance control used in ballet training.

Ballet exercises were selected and modified to make them easy to learn and to serve functional purposes of daily life. The materials for the balance training programme consist of a warm up, ballet exercises which are done with and without support of the barre, jumps and a cool-down. The materials offer the grounds for multimodal training for older adults, incorporating strength training, mobility, agility, body awareness and dual and multi-tasking. The function-specific ballet exercises selected are grounded on the principles of progression, overload and individuality. Together they ensure successful learning in a group framework and allow flexibility for adjusting exercises depending on the needs of each of the participants.

---

Key words: balance, postural control, older adults, ballet, training programme

## CONTENTS

1	INTRODUCTION.....	5
2	OBJECTIVE, PURPOSE, RESEARCH QUESTIONS AND METHOD OF THE STUDY.....	7
2.1	Objective, purpose and research questions.....	7
2.2	Method of the study.....	7
3	FUNDAMENTALS OF BALANCE CONTROL.....	9
3.1	Balance, stability and limits of stability.....	9
3.2	Components of postural control.....	10
3.2.1	Biomechanical limits.....	11
3.2.2	Sensory strategies.....	13
3.2.3	Postural orientation in space.....	14
3.2.4	Moving strategies.....	15
3.2.5	Control of dynamics.....	16
3.2.6	Cognitive resources.....	17
4	PRINCIPLES OF BALANCE TRAINING FOR OLDER ADULTS.....	18
4.1	Effect of age on balance and the rationale for the goals of balance training for older adults.....	18
4.1.1	Age-related changes in biomechanical limits and rationale for improving muscle strength, endurance and power.....	18
4.1.2	Age-related changes in biomechanical limits and rationale for improving joint mobility.....	19
4.1.3	Age-related changes in biomechanical limits and rationale for improving functional characteristics of the feet.....	20
4.1.4	Age-related changes in biomechanical limits rationale for improving postural alignment.....	20
4.1.5	Rationale for improving sensory integration and orientation in space in older adults.....	21
4.1.6	Rationale for practicing movement strategies with older adults... ..	23
4.1.7	Rationale for improving dynamic control in older adults.....	24
4.1.8	Rationale for practicing dual and multitask activities with older adults.....	25
4.2	Applying principles of basic exercise physiology and motor learning to balance training for older adults.....	25
4.3	Model of interacting factors in balance training.....	27
5	BALLET-EXERCISE AS A TOOL FOR DEVELOPING BALANCE.....	28
5.1	Strategies of ballet-exercise to improve biomechanical resources of balance.....	28
5.2	Use of sensory strategies in ballet-exercise.....	31
5.3	Postural orientation in space.....	31

5.4	Movement strategies in ballet training.....	33
5.5	Dynamic control in ballet training .....	34
5.6	Integration of movement and cognition in ballet training .....	34
6	PRACTICAL APPLICATION.....	36
6.1	Sequence and the main principles of the ballet class.....	36
6.2	Is ballet exercise safe and suitable for older adults?.....	38
6.3	Benefits of the ballet-based balance training for older adults .....	39
6.4	Designing the balance training .....	41
6.4.1	The goals for the balance training based on the components of postural control.....	41
6.4.2	Warm-up and cool-off.....	42
6.4.3	Grounds for the choice and modifications of the barre ballet exercises.....	43
6.4.4	Functional benefits of the chosen ballet exercises .....	46
6.4.5	Visual guide to the execution of the chosen ballet barre exercises.....	50
6.4.6	General information and principles of progression when teaching the ballet exercises.....	54
6.4.7	Summary of principles of manipulating sensory systems during exercises.....	56
6.4.8	Practical tips and suggestions for introducing the ballet exercises to older adults .....	57
6.5	Methods, process description and schedule of the thesis.....	57
7	DISCUSSION .....	59
	REFERENCES.....	62

## 1 INTRODUCTION

The idea for this thesis came from the practical training period in one of the Health Centers of the city of Tampere in autumn 2014, where I helped to supervise an adults' mixed-diagnosis group for improving balance. These classes are mainly organized for improving balance in elderly people with decreased physical function and people with balance disorder due to various chronic diseases. One of the participants told me that she used to dance but now with diagnosis of a neurological disease "her dances are danced"; therefore, her only option was to attend physiotherapy groups to help to maintain her mobility, strength and balance.

Increasingly, older adults are offered and expect new experiences in their active leisure time. Hobbies that once were considered appropriate for young people are available also for seniors. However, once a person's physical function is impaired or one has developed a chronic condition, the participation is often restricted. Therefore it is not uncommon that those people often have less social interaction and a decrease in both quality of life and their mental state. People with physical impairment often rely on physiotherapy provided by the health care services, which tend to provide functional programmes supporting basic health needs. Existing programmes are definitely essential; however, alternative creative approaches should be applied to offer patients new experiences or ways for self-exploration. For example, for those patients who might live with increasing disability for decades and continue to depend on the health care services.

The Chartered Society of Physiotherapy (2015) emphasizes a "whole person" approach, helping healthy people of all ages or those affected by injury, illness or disease to improve their quality of life, including their physical, psychological, emotional and social well-being. Physiotherapy practice is science-based and it may implement various researched effective approaches and techniques to achieve needs of the patient / client (WCPT 2014). One of the main goals of physiotherapy is to support a client's independence and promote a long-lasting, healthy lifestyle. Integrating different practices such as martial arts, Pilates, yoga and dance into physiotherapy might serve as a motivational tool, allowing new experience and encouraging participants to start a new healthy hobby.

As a dance teacher as my previous professional education, I am particularly interested in utilizing my dance background in physiotherapy practice. Therefore, when a patient in a balance class told me about not being able to dance any more, I instantly responded that even in her circumstances dance should be possible. Dance has been used in health care as a form of therapy for patients of different ages with various physical problems and chronic illnesses. Research examining dance-based interventions for elderly populations have indicated that it has a physiological impact on aerobic-power, lower body muscle endurance, strength, flexibility, gait and balance (Federici, Bellagamba & Rocchi 2005; Keogh et al. 2009). Also, research examining dance for people with Parkinson's disease has demonstrated that it may improve balance as well as quality of life (Huston & McGill 2013).

Among various styles of dance, ballet in particular is of great value in development of balance (Schmit, Regis & Riley 2005). There has been a growing interest in ballet dancers' body alignment control, posture, balance and proprioception among scientists involved in dance research (Hugel et al. 1999; Pedersen, Erleben & Sporring 2006; Martinez et al. 2014). There is, however, little research carried out on effective use of a ballet exercise principles for purposes and benefits of physiotherapy. Therefore, I want to explore research in both physiotherapy and dance on principles of balance training and on dance interventions that had been carried out for elderly people with balance impairment. After reviewing the literature, I will build a theoretical and practical scaffold for a ballet exercise-based balance training programme for older adults.

## **2 OBJECTIVE, PURPOSE, RESEARCH QUESTIONS AND METHOD OF THE STUDY**

### **2.1 Objective, purpose and research questions**

The objective of this thesis is to combine ballet exercise and its teaching principles with physiotherapy practice for improving balance in elderly patients with balance impairment. The purpose is to build theoretical and practical grounds for a balance training programme based on ballet exercises. A further objective is to enhance the knowledge of the physiotherapy students and professionals on some of the principles used in ballet training to develop skills essential for balance. Therefore, the outcome of the study might offer to physiotherapists an alternative useful tool for improving balance. Furthermore, it may represent a motivating approach to physiotherapy as well as an enriching learning experience for patients.

The research questions are:

1. What are the essential elements of effective balance training for older adults?
2. How does ballet training address development of balance?
3. Which ballet exercises are applicable to a balance training programme for older adults?
4. How do ballet exercises need to be adjusted or modified to make them appropriate for older adults with balance impairments?

### **2.2 Method of the study**

This bachelor thesis will be conducted out as a design study, also referred to as design-based research (DBR). This research method is widely used in education. One of the main goals of the design-based study is to make theoretical research relevant to practice. The result of the study might be a design of a new, usually innovative programme or curriculum with concrete guidelines, tools and other useful materials. The study documents the whole process underlying the new design, such as theoretical framework, goals of the design, how and why the materials were chosen and modified in order to achieve the final result. (Reimann, 2010.)

Existing research shows the effect of different kinds of training on balance of older adults and the effect of ballet training on the different aspects of physical fitness (Hugel et al. 1999; Schmit et al. 2004; Horak 2006; Pedersen et al. 2006; Silsupadol et al. 2006; Oddsson, Boissy & Melzer 2007; Martinez et al. 2014). I will use the design-based research method to collect research in both physiotherapy and dance, which is relevant to the process of building a balance training programme for older adults and then to apply the theoretical framework to practice. The outcome of the study will be guiding materials for a ballet exercise-based balance training programme for older adults.



### 3 FUNDAMENTALS OF BALANCE CONTROL

Balance is essential to be able to move safely and therefore to live and function independently. Balance impairments may occur due to advancing age or as a consequence of disease, which may increase the risk of falls and fall related injuries (Oddsson, Boissy & Melzer 2007). Falls have been identified as a major health problem among older people as well as a significant cause of health and medical care costs (Pajala, 2012, 7-8). Individuals with balance impairment are often advised physiotherapy to improve balance control and decrease risk of falling (Silsupadol et al. 2006). In the physiotherapy field, the most commonly researched groups with an increased risk for falls include older adults, especially women and people with neurological conditions such as Parkinson's disease and multiple sclerosis (Silsupadol et al. 2006; Baker, Atlantis & Singh 2007; Sherrington et al. 2008; Keogh et al. 2009).

In order to detect the causes of balance impairments and to create effective strategies to improve balance, we have to understand, first, how the central nervous system controls balance and, second, how it controls many other physiological systems, which allow a person to stand, walk and function efficiently and safely, and how these systems contribute to balance control (Horak 2006; Silsupadol et al. 2006; Pollock et al. 2000). Before that, however, an accurate understanding of definitions such as "balance", "stability" and "postural control" is required (Pollock et al. 2000, Horak 2006).

#### 3.1 Balance, stability and limits of stability

Balance has been widely researched for decades and its definition has changed over the years. The mechanical definition of balance (equilibrium) refers to an ability of a static object to control its own center of mass over the base of support (Hall 1991 as cited in Pollock et al. 2000). Applying this definition to a human, static balance is an ability of an individual to maintain his trunk centered over the base of support, which in standing position would be the feet (Horak 2006). Dynamic balance requires control over the center of gravity while changing position or moving (Winter et al. 1990).

Mechanical principles establish that stability occurs when an object's center of gravity is within the base of support. Stability increases when the base of support is larger, the center of gravity is lower or the center of gravity is more centered. (Bell 1998.) Limits of stability are within the space, which allows a person to lean over without changing the base of support (Horak 2006). For example, in standing position a person performs small corrective sways in order to maintain a body centered over the feet without shifting them. These sways may be performed in anterior-posterior as well as in medial-lateral directions, within the limits of stability (Nasher 1990 as cited in Bandy & Sanders 2013, 252-253). Therefore, balance is not a position but a space within the limits of stability, which is affected by joint range of motion, muscle strength and available sensory input to detect the limits (Horak 2006).

### **3.2 Components of postural control**

Postural control is essential to maintain balance of the body, with its highly placed center of mass, over the feet, which are relatively small in size (Herdman & Clendaniel 2014, 29). When the center of gravity shifts over the base of support or sway occurs outside the limits of stability, postural control is required to prevent falling (Winter et al. 1990). Pollock (2000) describes postural control (or “balance control”) as “an ability to maintain, achieve and restore static and dynamic balance”. Postural control depends on a complex interaction of multiple sensorimotor mechanisms and many balance control systems are contributing to a person’s balance (Horak 2006). Horak (2006) summarizes six important resources that contribute to postural control, which include sensory strategies, orientation in space, biomechanical limits, movement strategies, control of dynamics and cognitive skills. The table 1 describes the six systems underlying the postural control and their components.

TABLE 1. The six resources of postural control with contributing components

<b>Resources of Postural Control</b>					
<b>Biomechanical limits</b>	<b>Sensory strategies</b>	<b>Orientation in space</b>	<b>Movement strategies</b>	<b>Control of dynamics</b>	<b>Cognitive resources</b>
Base of support (feet)	Visual system	Postural alignment with respect to gravity (vestibular system)	Ankle strategy	Gaze stabilization (vestibular-ocular reflex)	Previous motor experiences
Muscle strength in lower extremities	Somatosensory system: proprioceptive, cutaneous, kinesthesia, pain	Postural alignment with respect to verticality (visual, vestibular system)	Hip strategy	Components of the biomechanical limits	Previous cognitive experiences
Range of motion (ankle and hips)	Vestibular system: sensory input and motor output (reflexes)	Somatosensory perception of body alignment	Stepping strategy	Stabilizing muscles' activation patterns	Dividing resources between motor and cognitive task
Posture	Central Nervous System: integration and re-weighting		Voluntary, anticipatory and reactive strategies		

Balance impairment may be caused by disorders of one or more of the components involved in postural control (Horak et al. 2007). For example, imbalance may occur due to neuropathy, decrease in muscle strength or a deficit of cognitive resources. Therefore, a proper understanding of each component is critical for appropriate treatment of balance impairments (Horak et al. 2007).

### 3.2.1 Biomechanical limits

Biomechanical constraints in stance include the base of support, the feet, postural alignment, joint mobility and functional muscle strength in the hips and ankles (Horak et al. 2009). While standing or walking, balance is influenced by the size, strength, mobility,

proprioception and control of the feet (Horak 2006). Previous research demonstrates that toe, foot and ankle strength, flexibility and tactile information have a significant role in predicting balance and functional ability, particularly among the elderly (Menz, Morris & Lord 2006; Uritani et al. 2014). Menz and colleagues (2006) particularly emphasize contribution of ankle flexibility, plantar tactile sensation and strength of toe plantar flexor muscles to the balance of older people. Therefore, pain, neuropathy, deformities, decrease in muscle strength and flexibility in the feet and ankle will affect balance (Horak 2006; Menz, Morris & Lord 2006).

Postural alignment might also cause biomechanical limitation (Horak 1987). When standing, stability is challenged by a person's high centre of mass and small base of support. Ankle plantar- and dorsiflexors as well as invertor and evertor muscle activity is of an important role to counteract body sway. An efficient posture is essential for an upright alignment, for optimal distribution of body weight, for even load on joints and for efficient movement patterns. Changes in postural alignment, such as asymmetric weight bearing or forward head and thoracic kyphosis, may cause restrictions to the limits of stability, reduce mobility of joints and cause weaknesses in the core, hips and ankle muscles, thus decreasing of postural stability. (Horak et al. 2009; O'Sullivan, Schmitz & Fulk 2014, 424-425.)

An ability to keep the body centered within the limits of stability is also controlled by the central nervous system. An accurate internal representation of the limits of stability is necessary for an adequate choice of moving strategies to maintain balance. (Horak 2006.) Thus, a false internal model of the limits of stability might lead to incorrect body alignment and also activation of the wrong strategies to recover equilibrium. For example, older people at high risk of falling may have a smaller representation of the limits of stability and instead of using small corrective movements they tend to respond with exaggerated postural responses to a small perturbation either lowering the center of gravity or taking a step to enlarge the base of support. In contrast, people with an enlarged inner representation of the limits of stability might not take a corrective step when required and lose balance. (Horak 2006; Herdman & Clendaniel 2014, 34, 40.)

### 3.2.2 Sensory strategies

Postural control depends on the three major sensory systems (visual, somatosensory and vestibular) to sense the threat to stability, on central nervous system to integrate the information and combine with previous experiences and, finally, on the musculoskeletal system to respond with appropriate coordinated muscular actions and regulate body posture and movement (Winter et al. 1990). Sensory input is essential for spatial orientation of the body (Horak 2006).

The somatosensory system includes, first, the cutaneous senses, such as the sensing of touch, vibration, temperature and pressure; then, proprioception, which is perception derived from the muscles and tendons about the position of body segments in relation to each other; third, kinesthetic sensibility, which is an awareness of body position and movement; and finally perception of pain (Winter 1995). The somatosensory system, therefore, provides complex information from the feet about the surface and from different body parts about their relation to each other. Proprioceptive information is the dominant sensory input for healthy adults especially on a firm stable surface. (Shumway-Cook & Horak 1986.)

When proprioceptive cues are unreliable, for example when standing on a soft uneven surface, the visual system will provide information about the surroundings. Information from the visual system helps an individual to move safely. In case of a conflict between the visual and somatosensory inputs, information from the vestibular system will be dominant. (Shumway-Cook & Horak 1986.) The vestibular system provides sensory information about the position of the head and trunk in relation to gravity. The vestibular system also has an important motor function in postural control. Motor output of the vestibular motor system consists of vestibular-ocular, vestibulospinal and vestibulocollic reflexes. The vestibular-ocular reflex allows accurate dynamic vision by maintaining stable vision during head and body motion. The vestibulospinal reflex acts to stabilize the head and trunk and to maintain an upright position by initiating strategies to restore balance during unexpected perturbations. The vestibulocollic reflex stabilizes the head, activating appropriate neck muscles. (Herdman & Clendaniel 2014, 11-12.)

Sensory strategies used in regulating balance, however, are not simply reflexes, which convert sensory input into motor output (Herdman & Clendaniel 2014, 15). Instead, they

play an important role in a multicomponent balance skill, which the nervous system learns and develops with experience (Horak et al.1997). Horak (2006) divides sensory strategies into sensory integration and sensory reweighting. The role of sensory integration is to provide accurate information to the central nervous system about body position and motion. Thus, proprioceptive pathways derive information from many body segments, the visual system informs about the surrounding environment and the visual system obtains information about body sway. The central nervous system then combines the available sensory information and weighs it according to its relevance. This way it provides orientation in space and responds with appropriate postural adjustments, depending on the goal of action. (Herdman & Clendaniel 2014, 33.) Reassessment of the sensory input is essential to maintain stability when a person encounters various changes in the environment (Horak 2006). Examples in daily life could be changes in lighting when entering a dim room or walking along the street that changes from a concrete a surface to a cobblestone one.

Loss of one of the sensory systems, however, is not a predictor of functional disability. In case of impairment of one of the sensory systems, the equilibrium control center can choose another source of orientation, relying on information from the available sensory systems. However, a deficit in multiple sensory systems may result in functional loss, such as inability to move and perform everyday activities safely. (Horak 2006, Herdman & Clendaniel 2014, 34.)

### **3.2.3 Postural orientation in space**

Postural orientation in space depends on the central nervous system for perception of gravity and verticality, which relies on the information derived from the vision, perception of surface and body alignment (Herdman & Clendaniel 2014, 11-12). The somatosensory system contributes to the postural orientation by sensing the alignment of body segments in relation to each other, the visual system provides an internal representation of visual verticality, whereas the vestibular system aligns the body with respect to verticality. The vestibular system has an important role in body alignment, being able to sense the direction of gravity and trigger necessary motor postural responses to maintain balance. (Herdman & Clendaniel 2014, 32.)

The central nervous system aligns the body according to an internal representation model of the center of gravity. This model is based on the combined information provided by sensory systems. Correct perception of the center of gravity helps to maintain the body's center of mass safely within the limits of stability. People with vestibular pathology, might align their body along with the edges of their limit of stability, causing a higher risk of falling. (Herdman & Clendaniel 2014, 33.)

### **3.2.4 Moving strategies**

The central nervous system uses the internal representation of the limits of stability to determine how to move in order to adjust or correct equilibrium. Moving strategies are applied by the central nervous system in response to internal or external perturbations. Depending on the evaluation of the threat to stability, the CNS will react with the ankle, hip or stepping strategy to prevent loss of balance. Factors determining which strategy to use include speed and intensity of the perturbation, quality of the support surface and the extent of the displacement of the center of the body. Consequently, small disturbances on a firm surface can be counteracted with the ankle strategy, which involves movement around the ankle joints and minimal movement of knee or hip joints. If the disturbance exceeds the capacity of the ankle muscles' reaction, the hip strategy will be applied to redistribute the center of mass within the available base of support. The hip strategy involves rapid movements at the hips and is typically used on the uneven, narrow or moving surface. Lastly, when bigger forces are applied to displace body's center out of the limits of stability, taking a step will allow enlarging the base of support recovering stability. (Horak 1987; Horak 2006; Herdman & Clendaniel 2014, 39.) In response to anterior or posterior displacement a corrective step forward or backward will stabilize the body. The common response to the lateral displacement is a cross-over step (O'Sullivan, Schmitz & Fulk 2014, 425).

Movement strategies can be triggered as a reaction to anticipatory or unexpected disturbances and as a postural adjustments prior to a voluntary movement (Horak 1987; Pollock 2000). These postural synergies are, however, not merely a motor reflex but a learned, task-specific and flexible motor response, which can be taught through voluntary exercises. Limitations such as reduced joint range of motion, muscular strength and endurance

or pain, swelling or joint instability can affect the choice of the movement strategies to maintain balance. For example, reduced range of motion and muscle strength in ankles will result in the compensatory hip or even step strategy as a reaction of a small perturbation. (Horak 1987.)

### **3.2.5 Control of dynamics**

In walking, the body's center of mass does not lie within the base of support in contrast to standing. Instead, it is transferred from one base of support to another, from foot to foot. Therefore control of dynamic balance is challenged by a yet smaller and less stable base of support. (Horak 2006; Woollacott & Tang 1997.)

The task of transferring the body forward requires the trunk and the supporting hip and foot to counteract the weight of the body, which falls outside of the medial border of the foot. This creates potential for mediolateral instability in the hips and feet. Therefore, the hip abductors, lower trunk lateral flexors and ankle invertor and evertor muscles play an important role in maintaining balance while walking. (Woollacott & Tang 1997.)

Keeping head and eyes stable also contributes to stability while walking, running or jumping. Stabilizing of the head and eyes is the strategy used by the central nervous system to control equilibrium. Even though the head is involved in dynamic motion, it is held relatively stable in relation to gravity while the rest of the body might be performing large motions. Stabilizing neck muscle activation occurs before the anticipatory motion to maintain the head stable. (Herdman & Clendaniel 2014, 42-43.) These anticipatory postural responses of the muscles around the spine prepare the head and trunk to take compensatory adjustments prior to expected disturbance to postural balance, which are associated with limb movements or locomotion (Hodges & Richardson 1997; Woollacott & Tang 1997).



### 3.2.6 Cognitive resources

Many parts of the brain are involved in maintaining upright posture and balance. The vestibular nuclear complex, which is located in the brain stem, is responsible for collecting and integrating sensory information in combination with other parts of the brain such as the cerebellum and cerebral cortex. The cerebellum contributes information on previously learned automatic movements, which were mastered due to repeatedly practiced motions involved in activities that require balance. The cerebral cortex in turn contributes to balance and postural control, providing cognitive information on previously learned experiences, which had an effect on a person's sense of balance, for example a memory of balance requirements on a slippery surface. Also, modifications of postural control may occur depending on cognitive goal of the activity. (Cullen & Sadeghi 2008; Herdman & Clendaniel 2014, 9-11.)

In addition, the cerebral cortex controls various functions among which are attention, mental calculation and memory (Jacobs & Horak 2007). Therefore, resources of the cerebral cortex are shared, contributing to both: postural control and cognitive processing. Thus, unfamiliar and difficult postural tasks will require more processing. Activities, which involve both cognitive thinking and postural control, might cause decline in reaction time and affect balance performance, leading to instability. (Silsupadol et al. 2006; Jacobs & Horak 2007; Beauchet et al. 2009.) These dual- or multitask activities, however, are necessary in everyday life, for example, talking while walking, crossing the road while paying attention to traffic or calculating a root in an unfamiliar place.

## **4 PRINCIPLES OF BALANCE TRAINING FOR OLDER ADULTS**

Depending on the assessment of which of the balance systems cause a balance deficit, specific training can be applied either to train the impaired system or practice to focus on other available systems in order to compensate for the loss of another (Horak 2006; O'Sullivan, Schmitz & Fulk 2014, 428). Group-based balance training, however, has to target various systems of balance control in order to benefit different members of the group.

In order to provide an effective balance training, it has to be specific to the balance function as well as comply with principles of exercise (Oddsson, Boissy & Melzer 2007). This chapter describes age-related changes in systems involved in balance control, reasoning for goals of balance training as well as essential principles of exercise for older adults.

### **4.1 Effect of age on balance and the rationale for the goals of balance training for older adults**

As mentioned earlier, dysfunction in one or a few of the balance systems does not necessarily lead to functional loss, as long as the other available systems efficiently compensate for it (Herdman & Clendaniel 2014, 481). Therefore, increasing age alone is not a risk factor for balance impairment. However, if the other balance components have a decreased ability to compensate, it may result in a balance deficit and an inability to live and function efficiently without external help. (Herdman & Clendaniel 2014, 482.)

#### **4.1.1 Age-related changes in biomechanical limits and rationale for improving muscle strength, endurance and power**

With advancing age, various resources of balance control progressively lessen their function (Horak 2006; Oddsson, Boissy & Melzer 2007). Age-related biomechanical restrictions on postural control include decline in muscle strength, flexed postural alignment, reduced joint range of motion and weaker somatosensory input (Horak, Wrisley & Frank 2009).

Muscle strength is vital for maintaining an upright posture, locomotion, balance and stability. Loss of muscle mass and muscle weakness in lower extremities, which are associated with aging, lead to balance and mobility deficits. (Jones & Rose 2005, 43-44.) Therefore, balance training for older adults, has to incorporate strength training of the muscles of the back, buttocks, thighs and calves (Jones & Rose 2005, 44-45; Pajala et al. 2011, 44-45). Important muscle groups for maintaining balance are ankle plantar and dorsiflexors, knee and hip flexor and extensor muscles, hip abductors as well as back's stabilizer muscles (Sakari-Rantala 2003; Jones & Rose 2005, 44).

Besides strength training, endurance and power training have an important role in balance training. Muscle strength is an ability of a muscle or a muscle group to produce force and overcome externally applied resistance. It requires moderate to maximum effort training with a low number of repetitions. Muscle endurance is responsible for muscle aerobic function, which is required when walking, bicycling and jogging and is trained at low to medium resistance with high repetitions. The ability to generate muscle power requires activation of type II muscle fibres (fast contracting and quick to fatigue), which activate in high intensity physical activity. Muscle power is essential for maintaining ability to move quickly against force, such as fast walking, getting up quickly and recovering balance after a slip or tripping. Muscle power is therefore an important factor in postural control. It is trained at low to medium resistance with several sets of repetition at high speed. (Sakari-Rantala 2003; Jones & Rose 2005, 44; Nelson et al. 2007)

#### **4.1.2 Age-related changes in biomechanical limits and rationale for improving joint mobility**

Joint mobility progressively diminishes with aging starting already from the age of about 30 years old. Limitations in joint movement can be a cause of prolonged physical inactivity or simply not engaging the full available joint range of motion in daily activities. Advancing age results in physiological changes in joints, which include stiffening of connective tissue, decrease in tissue water content, increase in collagen and crosslinking of fibres. As a result, stiffening of ligaments, tendons, joint capsules, fascia and muscles may occur around the joint. Therefore, using the capacity of joint mobility, for example taking bigger steps when walking and climbing stairs in daily life, and by stretching and

strengthening the muscles around the joint can maintain and improve joint mobility. (Sakari-Rantala 2003; Jones & Rose 2005, 45.) Effective muscle stretching has to be performed on the warmed-up muscle. Long-lasting (30-60 seconds) static stretching techniques especially in combination with active contraction are considered to be effective and safe for older adults. (Sakari-Rantala 2003; Bandy & Sanders 2013, 89–93.)

#### **4.1.3 Age-related changes in biomechanical limits and rationale for improving functional characteristics of the feet**

The feet and ankles provide a base of support in a stance; therefore, restrictions in their functional qualities such as foot posture, range of motion, strength, proprioception, tactile information, possible deformities and pain can result in impaired balance and increased risk for falls (Menz, Morris & Lord 2006). Reduced strength of plantar- and dorsiflexors, as well as invertors and evertors of ankles as well as decreased ankle joint range of motion are possible causes of avoiding the ankle strategy to maintain balance during standing. This results in use of the hip and stepping strategies even to a minor perturbation, which is common in older people. (Horak 2006; Herdman & Clendaniel 2014, 39.) Previous research demonstrates that toe, foot and ankle strength, flexibility and tactile information have a significant role in predicting balance and functional ability, particularly among the elderly (Menz, Morris & Lord 2006; Uritani et al. 2014). Menz and colleagues (2006) particularly emphasize contribution of the ankle flexibility, plantar tactile sensation (sense of touch) and strength of toe plantar flexor muscles to the balance of older people.

#### **4.1.4 Age-related changes in biomechanical limits rationale for improving postural alignment**

Age-associated changes in posture increase limitation in biomechanical components of balance. A forward tilted head, rounded shoulders, increased thoracic kyphosis, flexed hips, knees and ankles result in a shift of the body's center of mass backwards, in overloading joints, in straining muscles responsible for anti-gravity control and in decrease of stability limits. In addition, inaccurate inner representation of true vertical can affect postural alignment and cause instability. In this case, a person cannot voluntarily correct the faulty posture. (O'Sullivan, Schmitz & Fulk 2014, 425.)

The importance of optimal postural alignment has to be emphasized throughout the physical activity practice for older adults. In neutral postural alignment, weight is distributed evenly between the feet, the line of gravity falls slightly anterior to the ankle and knee joints, slightly posterior to the hip joint and anterior to the thoracic vertebrae and atlanto-occipital joint. The pelvis is kept in neutral position and natural spinal curves are present. In the case of faulty posture, the focus of the therapy should be made on musculoskeletal impairments, such as muscle weakness and reduced joint range of motion. Exercises for standing posture should emphasize an erect head position, open shoulders, neutral pelvic position, engagement of core stabilizing muscles and even weight distribution over both feet. Active exercises can include stretching of Achilles tendons, heel-rises, toe-rises, partial squats, kicks to the side and to the back. It is also important to encourage the use of correct posture in daily life. (O'Sullivan, Schmitz & Fulk 2014, 425-426.)

#### **4.1.5 Rationale for improving sensory integration and orientation in space in older adults**

Degenerative physiological changes in sensory systems (visual, vestibular and somatosensory) may affect balance, providing inaccurate or even distorted information about surroundings, base of support, perception of body alignment and verticality (Herdman & Clendaniel 2014, 480-485). Changes in each of the sensory system often results in slower processing of the input from the sensory systems as well as in their slower integration. Therefore, older people with multiple sensory deficit might not able to control the level of body sway when standing, which results in instability (Jones & Rose 2005, 214.)

Age-associated changes in the visual system include decrease in visual acuity, narrowed field of vision, reduced depth perception and contrast sensitivity. Changes in the somatosensory system, such as decline in the number of cutaneous receptors and number of sensory fibers, can be the cause of reduced proprioception and cutaneous perception in the feet and also can weaken awareness of the body alignment and movement. Physiological changes in vestibular system, such as degeneration of the nerve cells in the vestibular system, which detect the position and movements of the head and provide the central nervous system with the directions of gravity and verticality, can be the reason for

inaccurate perception of verticality and slower gaze stabilization after a quick head movement (Jones & Rose 2005, 214-215.) Aging of the central control of balance results in changes in automatic motor postural responses, such as slowed motor reaction time, muscle co-activation (agonist-antagonist stiffness) and the use of inefficient movement strategies (Tang & Woollacott 1998).

However, the sensory systems are adaptable to change. In absence of one sensory information other will be recruited to compensate for it. Moreover, when older adults are regularly exposed to situations that require and challenge sensory systems, they can learn to effectively adapt their postural responses. Exercises that are performed with eyes closed or with reduced vision require utilization of the somatosensory system. Furthermore, engaging eyes in following of an object is an effective way to challenge proprioception because visual and vestibular systems are deconstructed. Even though older adults with reduced somatosensory system rely on their vision more, they often do not use the vision system efficiently. An efficient way of using vision for controlling balance is the skill of fixating the gaze on a specific spot or target while performing a balance activity. The target should be on the eye level and preferably vertical. The next step is to add head movements and teach that the spot is still good to fixate but for a shorter time. In daily life it will help an older person to walk more steadily and not be afraid to turn the head, for example at a crosswalk while standing or walking. (Jones & Rose 2005, 214-216.)

Head movements should be incorporated into balance interventions because they are important for activation of the vestibular system. Also, turning and jumping, which are rarely done by older adults, are very effective activities for challenging the vestibular system. There is evidence that balance-jumping training effectively improves dynamic balance and is safe for independent older women living at home. (Karinkanta et al. 2007.) Standing or moving while tilting and turning the head relatively quickly also involves vestibular system and can help in reduction of dizziness in activities such as washing the head in the shower. Extra safety precautions might be required for members of the group with one or multiple sensory deficits. (Jones & Rose, 220-221.)

#### **4.1.6 Rationale for practicing movement strategies with older adults**

The inner representation of the limits of stability changes and can deteriorate with age providing either too small or too large range of the limits of stability (Horak 2006, Herdman & Clendaniel 2014, 34, 40). In those cases, an older person may either overreact with big movements to a small perturbation or may not take a step to prevent falling. The strategy of taking a rapid corrective step deteriorates with age, especially in dual- or multi task activities (Oddsson, Boissy & Melzer 2007). In addition, in older people at higher risk of fall, lateral postural sway increases, whereas lateral cross-over stepping strategy is used inefficiently, therefore causing higher lateral instability (Horak 2006).

Movement strategies are responsible for keeping the body stable in both voluntary and involuntary perturbations. Voluntary postural control and postural adjustments prior to a voluntary movement can be practiced in a variety of exercises, which include the transfer of weight or limb movement. Core muscles stabilization prior to a functional movement plays an essential role in correct muscle pattern activation. Involuntary postural adjustments, both anticipatory and unexpected, can also be practiced, using equipment such as a balance board, stability ball or an elastic band. (Jones & Rose 2005.)

Ankle, hip and stepping movement strategies can be also practiced in voluntarily exercises. The ankle strategy can be practiced, for example, by swaying back and forth, side to side and in a circular motion in slow tempo while keeping both feet on the floor. The hip strategy can be practiced in the same way just described, except at a faster tempo. The tandem stance is efficient for improving lateral hip strategy. The hip strategy can also be practiced while bending in different directions from the hips and reaching. In order to stimulate the use of the stepping strategy, balance task should become more challenging, for example walking along a narrow line. (Jones & Rose 2005, 222-224.) Also, taking anterior, posterior, lateral and cross-over steps as well as marching in place are considered effective exercises for training the stepping strategy (O'Sullivan, Schmitz & Fulk 2014, 427).

As has already been mentioned, the automatic responses to instability depend not only on voluntary actions, which are learned with practice and can be modified with goals and expectations, but also on reflexes of the central nervous system and integrated sensory information. Therefore, even though movement strategies can be practiced as voluntarily

movements, it might take years of training to develop faster reflex responses. (Oddsson, Boissy & Melzer 2007.)

#### **4.1.7 Rationale for improving dynamic control in older adults**

Control of dynamics in the elderly can be affected by various factors, among which are restrictions in range of motion, incorrect pattern of muscle activation and slower motor responses. In order to compensate for instability, an older person might use more conservative movement strategies when standing and moving. The common compensatory strategies for instability are wider base of support, flexed hips, knees and ankles, shorter stride, slower speed and holding onto an object in the environment. Furthermore, an older person with impairment in dynamic control can have difficulty shifting weight from side to side, forward-backward and in diagonal as well as maintaining stability while moving one or more limbs. (O'Sullivan, Schmitz & Fulk 2014, 425-426.)

In order to train stabilization control, exercise such as lifting one arm or leg from quadruped position might be useful. In this exercise the reduced base of support challenges stabilization control and requires adaptation strategies to distribute body weight on the available base of support and allow the limb movement. Dynamic control can be practiced when sitting and standing. Shifting weight without changing the base of support is a good exercise to explore limits of stability and to increase awareness of the limits. Walking at different speeds and using a variety of gait patterns, such as walking on toes, heels, the lateral edge of the feet, taking short and large steps in different directions and in different tempos helps to achieve a flexible and coordinated gait pattern. (Pajala et al. 2011.)

Anticipatory and reactive moving strategies can be practiced by moving and stopping on command or by quick changes from one step to another. These exercises increase attentional demand, because attention is divided between given motor and cognitive tasks. (Jones & Rose 2005, 224; O'Sullivan, Schmitz & Fulk 2014, 427.) Elements such as changing support area, standing on one foot, transferring weight from one foot to the other, bending of the trunk, reaching while standing and sitting help to practice demands of normal daily activities, which require postural control (Oddsson, Boissy & Melzer 2007).



#### **4.1.8 Rationale for practicing dual and multitask activities with older adults**

Lastly, attention demands on postural control are greater in older people. Studies show that older adults who perform poorly at dual-task activities are at higher risk of fall (Silsupadol et al. 2006). Since maintaining balance requires more concentration, secondary cognitive task while moving may affect cognitive processing of postural control, resulting in compromising postural stability (Beauchet et al. 2009; Herdman & Clendaniel 2014, 487). However, daily life involves activities, which involve performing of dual- and multitasks simultaneously. Therefore, it is important in balance training to select exercises requiring dual- or multiple tasks or high cognitive resources. (Jones & Rose 2005, 216; Pajala 2012, 23.)

Dual-task coordination process can be trained by combining any balance challenging exercise with a demanding starting position, an additional second motor task or an additional cognitive task. A tandem stance or standing on an uneven support are examples of demanding starting position. Kicking or catching a ball while standing or sitting on a therapy ball are examples of a second motor task. Finally, talking, counting or spelling while performing a motor task can serve as additional cognitive tasks. (O'Sullivan, Schmitz & Fulk 2014, 427.)

#### **4.2 Applying principles of basic exercise physiology and motor learning to balance training for older adults**

In order to be effective, any physical training programme has to comply with basic principles of exercise, which include overload, frequency, duration, specificity, cross-training, progression, individuality and awareness. These fundamental principles apply to any type of physical exercise and any category of individuals, regardless of age, sex or health status. (Oddsson, Boissy & Melzer 2007.)

The principle of **overload** indicates that to cause a training effect, challenge applied to the system should be greater than normally incurred. Overload can be increased by the demand of position in which the exercise is performed or by manipulating frequency, duration or intensity of an exercise. Frequency refers to the number of repetitions and

sets. Duration is the total time of an exercise. Intensity can be modified by the type of resistance, which include, body weight, free weights, elastic bands or manual resistance. (O'Sullivan, Schmitz & Fulk 2014, 419.)

**Accommodation** is an important exercise principle especially for older adults. Even though, exercises should comply with the principle of overload, older adults have to be encouraged to exercise to the best of their ability at that particular training session. In other words, older adults should not compare their performance to the previous one but instead they should learn to listen to their bodies and understand the signs of overstraining. (Jones & Rose 2005, 137-138.)

In order to be effective, exercises have to be **specific** to the trained function. In balance training exercises have to target various systems involved in postural control in systematic and progressive method. **Cross-training**, then, refers to exercises which combine a variety of training elements, placing greater demands on the systems trained. The **progression** principle requires updating of exercises and incorporating more challenges through the course of training. (Oddsson, Boissy & Melzer 2007; O'Sullivan, Schmitz & Fulk 2014, 418-420.)

It is important to incorporate the concept of **body awareness** into the balance training. Exploring the bodily sensations of how different positions and movements feel and affect balance as well as becoming aware of one's own capacities and limits is an important part of the training. In addition, skill awareness or understanding of the goal of an exercise and relating it to one's own skill level allows learner to practice autonomously. Body awareness is an important element of a successful motor learning. (Oddsson, Boissy & Melzer 2007; O'Sullivan, Schmitz & Fulk 2014, 398-399.)

In order to achieve optimal benefits, the group-based training programme should be **individualized** for each participant's needs and capacities. Instructing older adults requires adaptation to a wide range of abilities and medical conditions. (Jones & Rose 2005, 296-297.)

### **4.3 Model of interacting factors in balance training**

The principle underlying the model of interacting factors is that movement arises from an interaction of three elements, such as the individual, the task and the environment (O'Sullivan, Schmitz & Fulk 2014, 408). A movement or exercise should build varying task and environmental demands in a way, which does not exceed a participant's capabilities. Manipulating the task and environmental components helps to add specificity to an exercise. For example, in order to make an exercise more challenging for sensory system, combining an environmental component to the basic exercise can be performed. Environmental components include changes in the surface type, in lighting and in visual flow. For example, a one leg stance can be done on a foam roller or with eyes closed. If the goal of an exercise is to focus on the motor system, task demands can be applied. Task demands include performing exercises in more challenging positions, combining tasks (dual- or multiple tasks) or increasing intensity or repetitions. (Jones & Rose 2005, 216-217.)

The main goal is that the participant should be challenged but not overwhelmed by a balance task. Therefore, participants' individual capabilities have to be assessed prior to the exercise intervention and then re-assessed in a course of the intervention in order to make exercise sufficiently challenging and effective. (Jones & Rose 2005, 216-217.)

## **5 BALLET-EXERCISE AS A TOOL FOR DEVELOPING BALANCE**

Ballet is a form of art, which cultivates an aesthetic appearance and artistic experience. One of the important goals of the classical ballet performance is an image of an effortless and lightweight appearance, which is achieved by “long lines” created by extension of the arms and legs extension, by balancing on the toes and by the variety of leaps and jumps. All these elements require excellent control of balance, which plays a central role in ballet.

There is very little research that applies ballet exercise principles in physiotherapy practice. In relation to balance and postural control, however, ballet is a style of dance, which is remarkable for its high level of expertise (Schmit, Regis & Riley 2005). Researchers have been interested in balance control, movement strategies, proprioception and the use of visual input as components contributing to balance in classical ballet dancers (Hugel et al. 1999; Pedersen, Erleben & Sporring 2006; Martinez et al. 2014).

Since this study focuses on using ballet-exercise as a tool for physiotherapy intervention, this chapter will describe how ballet training addresses developing balance within the framework of functional performance requirements. The term “ballet training” does not cover the whole range of exercises used in the ballet class but is applied mostly to the ballet exercises done at the barre. Therefore, in order to go through the ballet balance strategies systematically and in relevance to the functional importance, they are organized into the six components of the balance system summarized by Horak (2006).

### **5.1 Strategies of ballet-exercise to improve biomechanical resources of balance**

In summary, biomechanical constraints while standing and walking include functional qualities of the feet (tactile information, proprioception, deformities, range of motion, strength), postural alignment, as well as joint mobility and functional muscle strength in lower extremities (Horak, Wrisley & Frank 2009). The topic of the proprioception will be discussed with sensory strategies and postural alignment in the postural orientation in space. Therefore, this thesis presents how ballet training affects muscle strength, power and endurance of lower extremities as well as joint range of motion.

Ballet exercise develops muscular strength, flexibility, coordination, balance and agility (Koutedakis & Jamurtas 2007). The goal of the early training is to strengthen the body and develop joint range of motion in order to provide correct alignment and postural control. These goals are achieved through the execution of the basic ballet exercises. (Paskevaska 2004, 26.)

Ballet class is strictly structured. It has been used and developed over hundred of years and, therefore, also offers an experience of a living tradition. The goals of the ballet exercises include warming up the muscles, developing muscle strength and conditioning the mind for responding to growing movement complexity. The precise sequence of the barre exercises is structured so that each exercise focuses on the particular muscle sensation and prepares the body for the next one. (Paskevaska 2004, 41-52.)

In the early stages of learning, a movement is localized and isolated. It allows concentration on learning the movement properly as well as inhibiting compensation from the other parts of the body. Even though an exercise may only involve movement of one part of the body, it usually covers more than one function. Thus, a common functional emphasis of ballet exercises is on the equilibrium, verticality and utilization of gravity. (Vaganova 1969, 11-15.) Working on one part of body at a time also allows to recognize and differentiate between the activation of the supporting muscles and the prime mover-muscles. Ballet emphasizes never sacrificing the stabilizing control of the body to the prime moving activity. (Paskevaska 2004, 42.)

The progression of the barre exercises is based on a logical development, comprising increasing demand on muscle activity, increasing complexity, larger amplitude of motion and gradual engagement of the entire body. This principle of training results in increased control, flexibility, coordination and efficient patterns of muscle activation. It develops the skill of optimizing motor synergies, which allows to perform movements with increased accuracy and with reduced muscle tension. (Bläsing et al. 2012.)

The stabilizing control is gained from the muscles and passive structures around the joints, which stabilize the body through the base leg(s) and the trunk. For example, in a forward leg lift (*relevé lent*), muscles which produce the movement include the quadriceps, the sartorius, the tensor fasciae latae and the deep external rotator muscles as well

as hip flexors as the lifting increases. The role of the stabilizing muscles of the back and abdomen is to support the upper body and prevent counteracting to the lower limb's movement, which in turn assist the elevation of the leg. The stabilizing structures of the supporting leg, which are majorly ligaments and muscles around the hip joint provide correct alignment of the body in relation to the line of gravity. (Paskevaska 2004, 24-25.)

Each exercise of the ballet class promotes strength and range of motion of the lower extremities. Specific attention is paid on the feet and the hips. Many of the bar exercises involve ankle plantar and dorsiflexion with bearing of the weight and without. Mobility at the hip joint is ensured by performing exercises to different directions and at gradually larger amplitudes. The range of motion is also trained through muscle activity. For example, classical ballet technique demands achievement of maximal active external rotation of the hips or "turnout", which is supported by active contraction of the gluteus maximus and the six deep external rotator muscles (piriformis, obturator internus, obturator externus, quadratus femoris, gemellus superior, and gemellus inferior). (Scherman, Mayall & Tasker 2014.) One of the reasons for turnout is to obtain maximal hip flexibility to allow high leg elevation. Thus, the abduction of the hip is in correlation with the external rotation of the hips. (Kushner et al. 1990.)

Muscular endurance is developed through repetition of the basic exercises. At first, ballet combinations are shorter and done in slow tempo, later number of repetition grows and the movements are done at faster tempo. Some ballet exercises require quick and sharp movements and some are done at a faster tempo, allowing to train muscle power which is required for jumps and leaps. (Paskevaska 2004, 24-25.)

Recent research demonstrates that traditional ballet training is not sufficient enough to access the fitness level of ballet dancers. It is generally understood that ballet dancers require additional strength training to prevent injuries. (Koutedakis & Jamurtas 2007.) For the purpose of balance training, however, the ballet exercises are suitable alternative, providing challenge to the postural control and directly incorporating muscle strength and coordination, which are the requirements of the balance training exercises (Oddsson, Boissy & Melzer 2007).

## **5.2 Use of sensory strategies in ballet-exercise**

Proprioception and vision are the two sensory strategies commonly used by ballet dancers (Hugel et al. 1999). Research on sensory strategies for postural stability among ballet dancers reveal greater visual dependence to maintain balance. Ballet exercise is done mostly in upright positions, the greater part of the exercises are done in front of the mirror, which serves as a tool for feedback. In addition, gaze stabilization strategy is used in all the turns and spins. Therefore, visual dependency is an apparent tendency to maintain balance in ballet practice (Costa, Ferreira & Felicio 2013).

Ballet exercises require focus on the somatosensory information from the feet and ankles because the majority of exercises are done standing on both feet or on one foot at a time. The somatosensory system is challenged by arm movements because, as a rule, movement of the hand is commonly followed by eyes, occupying both vision and vestibular system.

The vestibular system is challenged in ballet class with variety of head positions, such as slight flexion and extension, rotation and tilting. Also turns, spins and jumps used in ballet class serve as good exercises for challenging the vestibular system and the gaze stabilizing reflex. (Pasevska 2004, 40-42.)

## **5.3 Postural orientation in space**

In order to proceed to the strategies of awareness of postural alignment, used in ballet teaching, another approach to defining of the postural stability is required. Complying with the mechanical definition, human balance (equilibrium) refers to an ability of an individual to control his own center of mass (trunk) over the base of support (feet) (Hall 1991 as cited in Pollock et al. 2001). Another indication of postural stability is a center of pressure. The center of pressure demonstrates how the body's weight is distributed over the support area, which is in contact with the surface. When both feet are on the ground, each foot has a separate center of pressure. (Winter 1995.)

The difference of the two approaches to balance and stability is that one focuses on controlling the trunk over the feet, while another focuses on controlling directly the center of pressure of the body which is in the feet (Winter 1995; Pedersen, Erleben & Sporning

2006) The center of pressure is a more specific approach from the learner's point of view, because it emphasizes controlling the contact of the feet with the floor. The perfect balance can be achieved by positioning the center of mass directly over the center of pressure. This approach is commonly used in ballet. (Pedersen, Erleben & Sparring 2006.) For example, when balancing on one foot while performing movements with the other foot, the concept of "sending energy to the floor" helps to concentrate on the support foot and remain stable (Paskevskaja 2004, 42).

Ballet dancers exhibit more vertical alignment when moving and have highly developed skill of static postural control (Bläsining et al. 2012). Correct alignment of the body is a foundation of every movement in ballet (Vaganova 1969, 24). Body awareness exercises play a major role in teaching a correct alignment. When the essential areas of sensation in the body are emphasized, every student is then encouraged to find an alignment that feels right. For example, a student is encouraged to learn to recognize muscular sensations from the back and to control the correct position of spine in any position and movement. (Paskevskaja 2004, 26.)

Visualizing lengthening of the central axis of the trunk, which means lengthening the spine upward, promotes simultaneous activation of the abdominal muscles and the deep muscles of the spine. That, in turn, elongates the torso and helps to keep the thorax weight off the pelvis and lower extremities. The lengthened central axis of the trunk also supports the concept of central control of balance. Lengthening allows the alignment of the shoulders with hips over the same axis as well as distributes the body weight evenly on the available base of support. This energy-efficient body alignment allows an efficient performance of any movement or activity. (Bläsining et al. 2012.) For example, when bending the trunk to the side, an imaginary central axis will help to accomplish the motion through lengthening of the trunk and with a stabilizing control instead of collapsing the ribcage into the hip (Paskevskaja 2004, 26).

The pelvis, as a coordinating center of upper and lower body, is of a great importance in body alignment. When properly lengthening the spine, the pelvis will naturally obtain a correct position, which is not tilted either front or back. During exercises, the head and upper body has to stay straight on the leg or both legs to maintain balance. The weight of the body has to be equally distributed over the whole surface of the foot. The foot should



be aligned with the knee, the position of which is in turn conditioned by the degree of rotation at the hip joint. (Vaganova 1969, 25; Paskevskaja 2004, 26.)

A correctly aligned body requires a little muscular tension to maintain balance. In terms of an efficient performance of the movement, a well-aligned body ensures a wider range of motion and an efficient use of energy. As a consequence, if postural control requires an excessive muscle force and yet more force is needed to move a limb, the muscles are strained and the movement will appear rigid and more conservative movement patterns will be used. (Paskevskaja 2004, 27.)

#### **5.4 Movement strategies in ballet training**

An excessive muscle tension, rigid transitions and poor coordination between the trunk and limb movements can be the signs of inefficient postural control strategies. Excessive or unnecessary muscle activation is discouraged in ballet training since it might affect the quality of the whole performance. For example, excessive muscle activation in the feet will prevent a full contact with the floor when landing from a jump, triggering unnecessary ankle or even hip strategies, causing instability. (Paskevskaja, 2004, 43; Batson 2010)

Ballet exercises primarily involve use and practice of the anticipatory postural adjustments, which include activating the muscles of the trunk and the transfer of weight shortly before the movement of arms or legs (Pedersen, Erleben & Sparring 2006). Many ballet positions and exercises involve standing on one foot, moving on toes and bending the trunk, which challenge and activate the ankle, hip and stepping strategies. Since the basic feet positions in ballet class require external hip rotation, the ankles are challenged not only antero-posteriorly but also medio-laterally. In the ballet classes for children, however, exercises such as moving to a different types of music and unexpectedly stopping or improvising with a pair also activate the use of the reactive postural responses.

Studies that measured postural control strategies in ballet dancers reveal that the effect of ballet training mostly serves to challenge balance and does not transfer onto the balance challenges required in everyday life (Schmit, Regis & Riley 2005; Costa, Ferreira & Felicio 2013). The role of movement strategies is not usually discussed in ballet class. An understanding of how and when the movement responses are triggered might encourage

a ballet student to explore them and find his own solutions to maintaining the balance in challenging exercises. This might empower a student to find, practice and adopt new movement strategies instead of waiting for the teacher's feedback and advice. (Batson 2010.)

### **5.5 Dynamic control in ballet training**

The earlier described sensory strategies, such as focusing on the proprioception from the base of support and practicing the gaze stabilization while turning, are taught and continually practiced in the ballet class to control dynamical movements. Research shows that in static positions dancers rely on visual information more than on somatosensory. In dynamic balance measurements, a dancer's performance depended on the somatosensory system. (Hugel et al. 1999; Costa, Ferreira & Felicio 2013)

Other strategies important for dynamic movement involve anticipatory adjustments of the body prior to the movement, such as counteracting torsion at the hips. These include shifting of weight onto the supporting foot, lengthening of the spine and activation of the stabilizer-muscles of the hips and trunk. (Paskevaska, 2004, 24-48; Bläsing et al. 2012.)

Both control and flexibility of the lower extremities are essential factors of dynamic control. A special attention in terms of stability and mobility is given to the femoral joint because it initiates all the patterns of the lower limb movement as well as plays an important role in postural balance. Proximal control and mobility in the hip allows more effective coordination of the lower limbs with the pelvis and the upper body as well as minimizing the stress on the knee and ankle joints. It also results in a more centered weight distribution in the ankle joints, thus positively affecting foot alignment. (Paskevaska 2004, 29.)

### **5.6 Integration of movement and cognition in ballet training**

There are multiple cognitive and neural processes and strategies behind the exceptional physical skills of dancers, such as balance and postural control, highly demanding coordination and a remarkable memory for long movement sequences. During ballet practice,

a dancer's attention is focused on several cognitive tasks, among which are observing movements, memorizing them, reproducing them, coordinating movements of upper and lower body, following the music rhythm and reacting to a verbal and manual feedback. (Bläsing et al. 2012.)

Motor learning in ballet class depends on observing skills. While the teacher performs an exercise or dance combination the student forms a mental image of it, which he tries then to mimic. Thus, short-term memory is necessary to reproduce the pattern provided by the teacher. (Schmit, Regis & Riley 2005)

A strategy of marking a movement helps dancers to memorize longer movement sequences. "Marking" means either to show the movement with hands or to perform it with reduced range of motion and energy. This strategy helps to concentrate on other characteristics of the sequence such as pattern of movements, timing, use of space and direction. Consequently, it allows more energy and effort efficient physical performance of the sequence. (Bläsing et al. 2012.)

## 6 PRACTICAL APPLICATION

### 6.1 Sequence and the main principles of the ballet class

The structure of the ballet class have changed very little over the last hundred years. Although there are different methodologies of teaching ballet, the general sequence of the ballet class remains unchanged. The main tool in the ballet class is the barre, which is a rail made of wood or metal that is either attached to the walls or can be a portable model.

The class starts with pre-barre exercises, then proceeds with barre exercises, then continues with center exercises and finishes with allegro or jumps and dance combinations.

Pre-barre exercises can be light mobility exercises as well as different steps done to the music like marching, toe-walking, running and skipping. Then the class continues with barre exercises. Barre exercises can be done facing the barre, keeping both hands on it; sideways to the barre with only one hand support; and sometimes back to the barre with both hands at the lower level barre. The purpose of the barre exercises is to condition the body for the center exercise. It aims to develop joint range of motion, muscle strength, postural control and coordination. The barre offers physical and psychological support for safe execution of exercises. (Paskevskaja 2004, 49.)

The ballet exercises are described in the literature and in web sources in great detail (Vaganova 1969, Paskevskaja 2004). I will therefore merely present the names and prime goals of the standard barre exercises. However, it is important to remember that each of the barre exercise aims to develop more than one function, for example all of these exercises challenge postural control and balance.

TABLE 2. Standard ballet barre exercises

<b>Ballet exercise</b>	<b>Main purpose</b>
Demi and grand pliés	Centers and generally warms up the body.
Relevé	Warms up
Battements tendus	Warms up feet, ankles and hips, develops plantar flexion.
Battements jetés	Further warms up the feet and hips and is done in a sharp throwing motion, introducing a new dynamic component
Battement fondu	Gently flexes and extends the knees and increases mobility in the hip joints
Ronds de jambe par terre	Explores the rotation of the hip joint
Battements frappés	Strengthen the ankle and the foot
Ronds de jambe en l'air	Explores rotation in the knee joint. Enforces outward rotation at the hip
Développés	Challenges both control and legs' extension, further increases hip mobility
Petit battements	Isolates and enforces outward rotation at the hip and prepares legs for quick steps done at the center
Grands battements	Increases the hip joint mobility

Many of the barre exercises are repeated for the right and left side of the body, which allows development of muscular strength symmetrically. In addition, most of the barre exercises are performed in different directions (front, to the side and back). Each new exercise requires the knowledge and skill of the previous one. Therefore, it is important to focus on the accurate performance of each exercise in order to ensure success of the learning of the next movement. (Paskevaska2004, 50.) An accurate execution of exercises is also a basic principle in physiotherapy to secure that exercise is done safely and effectively (WPTS 2014).

In addition, the barre exercise can be performed in combination with raising on the toes (relevés), small jumps or slow muscle stretches and bends (port de bras). In the next part of the ballet class some of the bar exercises are performed in the centre. The exercises can also be combined into sequences and new steps and elements are gradually added.

The main goal of the centre exercises is challenging the balance and postural control. (Paskevaska 2004, 50.)

Next part of the class includes allegro or jump combinations, which progress in height and difficulty. Jump combinations can be done on the spot or as travelling jumps. Pointe work is the final part of the ballet class for girls, while boys continue with a variety of strength demanding jumps.

Each exercise is performed in a combination, which a student must memorize. Sequences are made manipulating rhythm, the number of repetitions, the direction, and coordination with simultaneous movements of arms, legs and head as well as the combination of new movements. Even though the ballet class is strictly structured, endless variations can be done to each of the exercise's sequences. (Paskevaska 2004, 50)

## **6.2 Is ballet exercise safe and suitable for older adults?**

Dance has been used in healthcare as a form of therapy for patients of different ages with various physical problems and chronic illnesses. Research examining dance-based interventions for elderly populations have indicated that it has physiological impact on aerobic-power, lower body muscle endurance, balance, strength, flexibility and gait (Federici et al. 2005; Keogh et al. 2009). Various studies have shown that dance also offers psychological benefits improving participants' subjective sense of well-being and quality of life (Connolly & Redding 2010; Houston & McGill 2013)

There is very little published research, which used ballet exercise or modified ballet exercise to improve balance. I found only one study, which used ballet exercise to explore its effect on balance and lower body muscular endurance in 12 individuals over 78 years old (Creighton & Fisher 2004). The results of the research showed significant improvement on muscular endurance but no significant changes in static or dynamic balance of the participants. However, ballet exercise can potentially be an effective exercise to improve balance and prevent falls because of its advantages associated with specificity to the systems underlying balance control, compliance with the physical exercise principles and integration of the motor and cognitive tasks (Silsupadol et al. 2006; Baker, Atlantis & Singh 2007; Oddsson, Boissy & Melzer 2007).

Recent studies reveal that the ballet training mostly serves balance control, which is required for dance performance rather than the functional challenges of daily life (Schmit, Regis & Riley 2005; Costa, Ferreira & Felicio 2013) Even though this factor is very important to consider, it does not undermine the carefully developed strategies, which specifically target the multiple systems of postural control. Also, as mentioned before, ballet exercise include many of the elements already used in physiotherapy practice. Therefore, by choosing functionally relevant exercises and by modifying them in a way, which will make them easy to learn and functionally valuable, will allow to implement ballet training to develop balance in older adults.

High incidents of injuries in classical ballet dancers occur due to factors such as performing on a hard floor surfaces, using thin sole shoes, fatigue and injuries in the knees and lower back due to the demand for an exaggerated outward rotation in the hips (Bowling 1989). Therefore, modifications of the ballet exercises such as exclusion of the high risk positions and exercises will make the exercises safer. External factors such as cold exercise room, hard or slippery floors also have to be considered as a risk factors for ballet exercise.

### **6.3 Benefits of the ballet-based balance training for older adults**

Ballet exercise can potentially be an effective exercise to improve balance and prevent falls in older adults because of its advantages associated with the specificity to the systems underlying balance control, compliance with the physical exercise principles, multi-modal training and integration of the motor and cognitive tasks (Silsupadol et al. 2006; Baker, Atlantis & Singh 2007; Oddsson, Boissy & Melzer 2007) In addition, most ballet exercises are done standing, which is closer to the functional daily life balance requirements. Furthermore, ballet training has many strategies to improve the function of the feet and ankles, which is an important risk factor for falls among elderly people (Menz, Morris & Lord 2006).

However, the goals of ballet training are different from the goals of balance training. Ballet focuses on the needs of the dance performance while balance training focuses on

the functional performance of daily life. It takes year after year of nearly every day practice to achieve a ballet required control and coordination. However, the threshold for achieving results required in everyday activities is fortunately much lower. Previous studies show that improvement in balance can be achieved already after 10-12 hours of systematic and specific balance training (Wolf et al. 2001; Silsupadol et al. 2006).

Both ballet and functional balance training have an identical prime goal, which is motion and prevention of injuries. For a dancer it means facing various challenges of new choreographies, while for a person with balance impairment it means independence while facing challenges of every day life. Analysis of the strategies of ballet training to achieve the goal of motion can serve as valuable tool of balance training.

Development of muscular strength is seen in dance as a tool for motion. This concept defines the specificity of strength exercises in ballet training. Firstly, ballet strengthening exercises are done standing, which specifically correlates with moving. Secondly, every exercise promotes an efficient alignment, which allows the capacities for moving. Thirdly, strength exercises focus on the synergy of muscle strength, which is required for coordinated and differentiated locomotion. Fourthly, muscle strength is developed in relation with the joint range of motion. (Paskevaska 2004, 42-60.) None of the ballet exercises should exhaust any particular muscle group, preventing further compensations (Paskevaska 2004, 49). Applying these principles in balance training will ensure a transferring effect of exercise on the ability to walk.

A balance programme, based on ballet exercises is cost-effective, because it does not require special equipment. The advantages of group exercise include a sense of social belonging, and a possibility to meet people with similar problems. Also, the group provides an effective learning environment. For example, when feedback is given to one member of the group or a question is asked, all the others can benefit from it.

Ballet can also offer an aesthetic experience because of the quality of movements as well as the music, which accompanies the movements. It may also expand the possibilities for participation and encourage older adults to continue practicing outside of the physiotherapy periods.



## **6.4 Designing the balance training**

The group-based balance programme can be from 45- to 60-minutes long and preferably done 2-3 times a week to obtain the benefits of the training (Oddsson, Boissy & Melzer 2007; Halvarsson, Franzén & Ståhle, 2015). Each session starts with 5-10 minutes of warm up, which involves exercises such as mobility exercises as well as different steps done to the music like marching and toe-walking in different directions and stopping to the music (reactive postural control). Then the ballet exercises can be performed at the barre and without the barre support. Relevés –demi pliés (squat and toe-raises) or jumps would be the last exercises performed at the barre. Different travelling and dance steps (examples on the page 23) and low intensity travelling jumps like galop should be done once between the barre exercises and at the end of it to practice dynamic balance in motion. The session will end with the cool-down exercises.

### **6.4.1 The goals for the balance training based on the components of postural control**

The six components of balance and postural control are organized here into the goals of the balance training, which are: improving postural alignment and static postural control, improving dynamic postural control, improving adaptation of balance ability to various task and environmental conditions, improving sensory strategies necessary in postural control (O'Sullivan, Schmitz & Fulk 2014, 424). The table 3 summarizes how the components of the six postural control systems are organized into the goals of the balance training programme.

TABLE 3. Components of postural control organized into goals of balance training

<b>Improving postural alignment and static postural control</b>	<b>Improving dynamic postural control</b>	<b>Improving adaptation of balance control to various tasks and environments</b>	<b>Improving sensory strategies involved in postural control</b>
<p><b>Biomechanical restrictions:</b></p> <ul style="list-style-type: none"> <li>▪ base of support</li> <li>▪ muscle strength of lower extremities</li> <li>▪ posture</li> </ul> <p><b>Movement strategies:</b> ankle and hip</p> <p><b>Postural orientation in space</b> awareness of postural alignment in respect to gravity and verticality</p>	<p><b>Control of dynamics</b></p> <ul style="list-style-type: none"> <li>▪ stabilization control;</li> <li>▪ joint range of motion;</li> <li>▪ muscle strength and power;</li> <li>▪ awareness of the limits of stability;</li> </ul> <p><b>Hip and stepping strategies</b></p> <p><b>Cognitive resources</b></p>	<ul style="list-style-type: none"> <li>▪ reactive balance control</li> <li>▪ muscle power of lower extremities;</li> <li>▪ joint range of motion,</li> </ul>	<p><b>Sensory strategies:</b> sensory activation, integration and compensation</p>

#### 6.4.2 Warm-up and cool-off

Warm-up and cool-down are necessary parts of each physical exercise session. They provide a safe transition to a more demanding exercise and recovery after it. Physiological benefits of warm-up include increased delivery of oxygen to working muscles, increased blood saturation of muscles, tendons and ligaments, increased speed of nervous impulses, increased somatosensory sensitivity and increased pulmonary circulation. Warming up is essential for older adults in order to decrease susceptibility to injury. It also plays an important social and emotional role in the practice session; therefore, the warm up has to be designed to provide opportunities to be successful in the movement and to achieve a feeling of overall enjoyment of the experience. Variations of warm-up exercises help the members of the group to adapt an appropriate level by implementing alternative. (Jones & Rose 2005, 144-148.)

Healthy older adults require at least 15 minutes of low-intensity movement that elevate heart rate and increases internal temperature. Progressing from small to larger range of motion and gradually gaining complexity are effective principles for warm-up exercises. Basic balance exercises are also appropriate for warm-up. Examples of these are transfers of weight and a variety of steps first on the spot, then forward, backward and afterwards sideways. However, to ensure success, complex combinations and complicated steps should be avoided. Emphasis should be made on proper body alignment and body mechanics as well as the importance of breathing during exercise. (Jones & Rose 2005, 144-148.)

The purpose of cool-down logically is to reduce body temperature and heart rate as well as promote a safe transition to the rest of the day. Older people require at least 10 minutes to return respiration and heart rate back to normal. An example of a cool-down exercise is a low-intensity gentle continuous movement, in which you keep arm movements small. Stretches should proceed from dynamic to static at the end of the cool-off, when the muscles and connective tissues are the most responsive. Stretching on the floor allows isolating one muscle group at a time while the rest of the body is relaxed. However, if the stretching on the floor is uncomfortable, static stretching can be performed while sitting on a chair. Preferably stretching would be applied to all areas of the body. (Jones & Rose 2005, 149.)

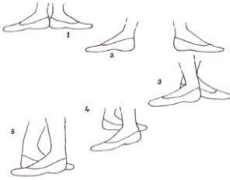
In addition, cooling off is an important time for reviewing the goals of the class as well as reflecting on the goals of the individuals. Potential goals for the day or until the next exercise session can be introduced and discussed in the group. This supports the emotional and social connection of the group members. (Jones & Rose 2005, 150.)

### **6.4.3 Grounds for the choice and modifications of the barre ballet exercises**

Some of the basic ballet exercises can be too demanding for an older adult to perform safely and correctly, while achieving a feeling of satisfaction. The feeling of success is, however, a necessary goal of the therapy to support and increase motivation for further learning (Jones & Rose 2005, 28).

Table 4 demonstrates which of the ballet exercises will be chosen for the programme for older adults. Since all the barre exercises contribute to the postural control, main principles for choosing the exercises include their functional purpose in daily life activities, their safety and the ease with which they can be learned ensuring a feeling of success.

TABLE 4. Ballet feet positions and barre exercises. Reasoning for accepting or not accepting the exercise and necessary modifications.

Ballet position and barre exercise	Modifications	Reason for modification
I, II, III, IV, V ballet positions of the feet 	Starting positions are either parallel position feet together or parallel position feet hip distance apart.	Parallel positions better contribute to the functional purposes of daily life (Clippinger 2007, 186).
Demi and grand pliés	Grand plié is not appropriate for older adults.	Demi plié serves functional goals. Maximal knee flexion in closed kinematic chain used in grand plié can be the cause of injuries (Clippinger 2007, 267).
Relevé		The movement is required in daily activities.
Battements tendus		Easy to learn and serves functional goals.
Battements tendu jetés		Easy to learn and serves functional goals.
Battement fondu	The cou-de-pied position is replaced with either pressing toes to the floor or with flexed ankle.	The position is complicating to learn correctly in a short time, also the modified positions better contribute to the strength and mobility of the foot.
Ronds de jambe par terre	First execute with the whole working leg so that the whole foot is on the ground, then with toes on the ground.	Useful movement for tactile feedback from the foot.
Battements frappés	Not chosen	May be difficult to learn correctly
Ronds de jambe en l'air	Not chosen	May be difficult to learn correctly
Développés	Not chosen	May be difficult to learn correctly
Petit battements	Not chosen	May be difficult to learn correctly
Grands battements	Not chosen	The throwing motion of the movement can be dangerous to the lumbar spine.
Jumps: sauté, echange		Jumps benefit to the muscle power of lower extremities and bone density.

#### 6.4.4 Functional benefits of the chosen ballet exercises

Table 5 describes the chosen ballet barre exercises: their goals, instruction on execution and examples of an exercise sequence. In the closed kinematic chain exercises, when the foot is fixed and in contact with the ground, hip flexion and extension occurs against gravity, in a concentric manner. This type of muscle activity occurs in all the exercises which require a plié or squat or bending of the body forward from the hips. These exercises contribute to the various activities of daily life such as sitting down and getting up off the chair. (Clippinger 2007, 188-189.)

The majority of the ballet exercises involve standing on one leg while the other one is moving. This particular feature makes these ballet exercises functionally valuable. In these exercises, the supporting leg acts in the closed kinematic chain. Concentric activation of the gluteus medius and minimus muscle is then essential to secure correct pelvic alignment and to avoid lateral tilt of the pelvis, which is caused by gravity. This function of hip abduction is very important in walking. It contributes to stability when the weight of the body is shifted on one foot. Therefore, it plays an important role in dynamic balance. (Clippinger 2007, 189.)

TABLE 5. Ballet barre exercises: goals, execution and examples of an exercise sequence. (Clippinger, 2007, 186-193, Paskevsksa, 2004, 53-65, Vaganova 1969, 26-35)

Exercise	Goals	Execution	Basic sequence (adding both motor and cognitive tasks)
<b>Demi plié</b>	<ul style="list-style-type: none"> <li>▪ To warm up the legs.</li> <li>▪ To strengthen hip flexors (Iliopsoas, rectus femoris, sartorius) and hip extensors (gluteus maximus and hamstrings muscles)</li> <li>▪ To strengthen triceps surae and tibialis anterior and extensor digitorum longus.</li> </ul>	<p>S.p*: parallel position feet together or parallel position feet apart.</p> <p>Bend the knees, so that knees are aligned with the toes and heels are pressed to the ground. Extend the knees.</p> <p>Note: activating of the gluteus maximus for extending the hips is encouraged</p>	<p>S.p: parallel position feet apart.</p> <p>Perform demi plies 8 times in slow tempo. Step to the parallel position feet together and revise the alignment. Repeat demi plies 8 times.</p> <p>(Optional: take hands off the bar and lower them along the sides of the body at the end of the sequence). Revise the alignment.</p>

	<ul style="list-style-type: none"> <li>▪ To stretch gently Achilles' tendon</li> <li>▪ To increase ankle dorsiflexion</li> <li>▪ To develop alignment and postural control</li> </ul>		Plie is often combined with bends of the body forward from the hips, keeping the back straight and sideways to each side.
<b>Revelé</b> (heel rises)	<ul style="list-style-type: none"> <li>▪ To warm up the legs</li> <li>▪ To strengthen triceps surae and tibialis anterior and extensor digitorum longus.</li> <li>▪ To develop ankle joint and toes mobility</li> </ul>	<p>S.p*: parallel position feet together or parallel position feet apart</p> <p>Lift both heels up as high as possible, keeping knees straight and trunk vertically aligned. Lower the heels down.</p>	<p>S.p*: parallel position feet apart.</p> <p>Perform relevés 8 times, then step to the parallel position feet together and repeat the exercise 8 times.</p>
<b>Battement tendu</b> (leg extentions)	<ul style="list-style-type: none"> <li>▪ To strengthen the whole leg and especially: triceps surae and tibialis anterior and extensor digitorum longus</li> <li>▪ To increase joint range of motion in the hips and ankles.</li> <li>▪ To practice shifting of weight.</li> <li>▪ Tactile sensation</li> </ul>	<p>S.p: parallel position feet together</p> <p>Extend the working leg to the given direction, stretch the ankle (plantar flexion) and point the toes. Keep the position. Return to the starting position. Revise the alignment.</p> <p><b>Note:</b> the toes are in contact with floor all through the exercise. Body is centered on the supporting leg.</p> <p>The position of the pelvis is not sacrificed to the leg's extension.</p>	<p>S.p: parallel position feet together</p> <p>Repeat battement tendu 4 times front, 4 times to the side, 4 times back, 4 times to the side in slow tempo.</p> <p>Repeat with the other leg.</p>
<b>Battement tendu</b> with the weight transfer.	<ul style="list-style-type: none"> <li>▪ To strengthen the whole leg and especially: triceps surae and tibialis anterior and extensor digitorum longus</li> <li>▪ To increase joint range of motion in the hips and ankles.</li> <li>▪ To practice shifting of weight</li> </ul>	<p>S.p: parallel position feet together</p> <p>Extend the working leg to the given direction, stretch the ankle (plantar flexion) and point the toes.</p> <p>Then bring the heel of the working leg down to the floor and shift the weight evenly between the feet. Point the toes of the working leg again.</p>	<p>S.p: parallel position feet together</p> <p>Repeat 2 times front, 2 times to the side, 2 times to the back in slow tempo.</p> <p>Repeat with the other leg.</p>

		Return to the starting position. Revise the alignment. Note: Level pelvic alignment.	
<b>Battements tendu</b> with ankle flexion.	<ul style="list-style-type: none"> <li>▪ To strengthen the whole leg and especially: triceps surae and tibialis anterior and extensor digitorum longus</li> <li>▪ To increase joint range of motion in the hips and ankles.</li> <li>▪ To practice shifting of weight</li> </ul>	<p>S.p: parallel position feet together</p> <p>Extend the working leg to the given direction, stretch the ankle (plantar flexion) and point the toes.</p> <p>Then dorsiflex the ankle, point the toes of the working leg again.</p> <p>Return to the starting position. Revise the alignment.</p> <p>Note: Level pelvic alignment.</p>	<p>S.p: parallel position feet together</p> <p>Repeat 2 times front, 2 times to the side, 2 times to the back in slow tempo.</p> <p>Repeat with the other leg.</p>
<b>Battements tendus jetés</b> preparing version (leg's lifts)	<ul style="list-style-type: none"> <li>▪ To strengthen the whole leg and especially: triceps surae and tibialis anterior and extensor digitorum longus</li> <li>▪ To increase joint range of motion in the hips and ankles.</li> <li>▪ To practice shifting of weight</li> </ul>	<p>S.p: parallel position feet together</p> <p>Extend the working leg in the given direction, stretch the ankle (plantar flexion) and point the toes. Lift the stretched working leg at 25-45 degrees. Lower the toes to the floor. Return to the starting position.</p> <p><b>Note:</b> leg's extension higher than 15 degrees requires pelvic tilt forward over the hip joint.</p>	<p>S.p: parallel position feet together</p> <p>Repeat 4 times front, 4 times to the side, 4 times to the back and 4 times to the side in slow tempo.</p> <p>Repeat with the other leg.</p>
<b>Battement tendu jetés</b> (fast and sharp extensions of the leg)	<ul style="list-style-type: none"> <li>▪ To strengthen the whole leg and especially: triceps surae and tibialis anterior and extensor digitorum longus</li> <li>▪ To increase joint range of motion in the hips and ankles.</li> <li>▪ To practice shifting of weight</li> <li>▪ To increase muscle power in the</li> </ul>	<p>S.p: parallel position feet together</p> <p>Extend the working leg in a strong, quick manner at 25-45 degrees to the given direction. Lower the toes to the floor. Return to the starting position.</p> <p><b>Note:</b> The working foot should "brush" the floor when opening and closing. Level pelvic alignment.</p>	<p>S.p: parallel position feet together</p> <p>Repeat 4 times front, 4 times to the side, 4 times to the back and 4 times to the side in slow tempo.</p> <p>Repeat with the other leg.</p>



	lower extremities.		
<b>Rond de jumbe par terre</b>	<ul style="list-style-type: none"> <li>▪ To challenge postural control</li> <li>▪ To strengthen gluteus medius and minimus of the supporting leg.</li> <li>▪ Increases toes, ankle, knee and hip mobility of the working leg.</li> <li>▪ To enhance tactile feedback from the working foot and toes.</li> </ul>	<p>S.p: parallel position feet together</p> <p>Extend the working leg forward, stretch the ankle (plantar flexion) and point the toes. Then sweep the working leg in semi-circle, first to the side and then continue to the back, keeping the toes on the ground. Return to the starting position. (en dehors)</p> <p>The exercise can also be performed starting to the back and circling to the front (en dedans).</p> <p><b>Note:</b> in the modified version of the exercise, the ball of the foot is remained on the floor instead of the tip of the toes.</p>	<p>S.p: parallel position feet together</p> <p>Repeat 4 rond de jumbe par terre en dehors and 4 en dedans in a slow tempo.</p> <p>Repaet with the other leg.</p> <p>Combine with bending of the torso to the front, to the side or backwards.</p>
<b>Battement fondu (modified version)</b> (controlled flexion and extension of both legs)	<ul style="list-style-type: none"> <li>▪ Greatly challenges postural control.</li> <li>▪ To develop coordination.</li> <li>▪ To strengthen the whole leg and especially: quadriceps and hamstrings, triceps surae and tibialis anterior and extensor digitorum longus</li> <li>▪ To strengthen gluteus medius and minimus of the supporting leg.</li> </ul>	<p>S.p: parallel position feet together</p> <p>Perform demi plié on the supporting leg while lifting the heel of the working leg off the ground and pressing toes (modified cou-de-pied position) Straighten the supporting leg and simultaneously extend the working leg with ankle stretched (plantar flexion) and toes pointed to the given direction.</p> <p><b>Note:</b> in the modified cou-de-pied position, toes press to the floor stretching the plantar muscles of the foot, however not bearing the weight of the body. The leg's extension can be done in the air at 25-45</p>	<p>S.p: parallel position feet together</p> <p>Repeat 4 battements fondus to the front, 4 to the side, 4 to the back and 4 to the side.</p> <p>Repeat with the other leg.</p>

	<ul style="list-style-type: none"> <li>▪ Increases toes, ankle, knee and hip mobility of the working leg.</li> </ul>	degree. Level pelvic alignment.	
<b>Jumps: sauté</b>	<ul style="list-style-type: none"> <li>▪ To strengthen: gluteus maximus, quadriceps and hamstrings, triceps surae and tibialis anterior and extensor digitorum longus</li> <li>▪ Develops ankle mobility</li> </ul>	<p>S.p: parallel position feet together or parallel position feet apart, demi plié.</p> <p>Jump from both feet, straightening the knees and pointing the toes in the air.</p>	<p>S.p: parallel position feet together, demi plié</p> <p>Repeat 4 sauté Pause: straighten knees and then demi plie Repeat 2 times in the 1st and then 2 times in the 2nd parallel position</p>
<b>Jumps: echappé</b>	<ul style="list-style-type: none"> <li>▪ To strengthen: gluteus maximus, quadriceps and hamstrings, triceps surae and tibialis anterior and extensor digitorum longus</li> <li>▪ Develops ankle mobility</li> </ul>	<p>S.p: parallel position feet together, demi plié</p> <p>Jump from the 1st to the 2nd parallel position and then jump again, back to the 1st parallel position</p>	<p>S.p: parallel position feet together, demi plié</p> <p>3 echappés. Pause. 3 echappés. Pause.</p>

\*S.p. = starting position

#### 6.4.5 Visual guide to the execution of the chosen ballet barre exercises

This chapter demonstrates some of the chosen ballet exercises in pictures. The main goal of the pictures is to provide an additional guidance to some of the exercises described in the table 5. The pictures 1 to 40 are arranged in order to show each step of each exercise. The first picture of the series represents the starting position; the following pictures represent each step of the execution of the given exercise and the last picture shows the finishing position.

The picture material provides only a general guide to the execution of the ballet exercises. Therefore, each exercise is performed only in one direction (either front or sideways), only in one position at the barre (either facing the barre or holding onto the barre with the right hand) and without added positions of the arms or head. Moreover, the person, who is demonstrating the exercises, is relatively new to the technique of the ballet exercise. Therefore, while all the feet positions are done correctly, alignment of the head and torso

is not neutral in some of the pictures especially when movements are done to the side at the 45 degree angle due to a challenging postural control requirements of the position. Another important detail is that the person demonstrating the exercises has limited plantar flexion; therefore, in order to avoid confusion it is important to use the pictures together with the instructions given in the table 5 or find the exercises from other sources.

Parallel position, feet together



Parallel position, feet apart



PICTURES 1, 2. Positions of the feet (Photo: Julia Van Camp 2015)



PICTURE 3, 4, 5. Demi pli  from parallel position feet together, facing the barre (Photo: Julia Van Camp 2015)



PICTURES 6, 7, 8. Demi pli  from parallel position feet apart, facing the barre (Photo: Julia Van Camp 2015)



PICTURES 9, 10,11. Relevé from parallel position feet together, facing the barre (Photo: Julia Van Camp 2015)



PICTURES 12, 13, 14. Battement tendu to the side, holding onto the barre with one hand (Photo: Julia Van Camp 2015)



PICTURES 15, 16, 17, 18, 19. Battement tendu with ankle flexion to the side, holding onto the barre with one hand (Photo: Julia Van Camp 2015)



PICTURES 20, 21, 22, 23, 24, 25. Battement tendu jeté preparing version to the side, holding onto the barre with one hand (Photo: Julia Van Camp 2015)



PICTURES 26, 27, 28. Battement tendu jeté to the side, holding onto the barre with one hand (Photo: Julia Van Camp 2015)

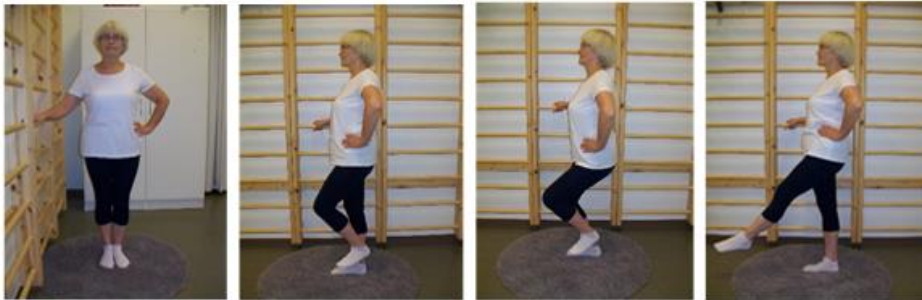


PICTURES 29,30,31. Rond de jambe par terre with the flat foot on the floor holding onto the barre with one hand (Photo: Julia Van Camp 2015)





PICTURES 32, 33, 34, 35. Modified battement fondu I front 45° (Photo: Julia Van Camp 2015)



PICTURES 36, 37, 38, 40. Modified battement fondu II front 45° (Photo: Julia Van Camp 2015)

#### **6.4.6 General information and principles of progression when teaching the ballet exercises.**

The ballet exercises have French names due to the origin of the first ballet teaching school. However, when teaching them in the framework of physiotherapy, familiar and functional names will make them more practical. When an exercise involves movement of one leg at a time, the leg, which bears the body weight is called “supporting leg” and the moving leg is called “working leg”.

All the barre exercises are first practised facing the barre while holding on to it with both hands. Once the skill is mastered, exercises can be done sideways to the barre, lightly holding on to the barre with one hand. This allows to combine the movements of the free arm to the foot work. When one hand on the bar, combinations are always repeated on both sides. Combinations can also be done back to the barre and finally not holding onto the barre at all. This gradual reduction in support allows to practice postural control with growing challenges. This also allows to adjust exercises to the different levels of the

members of the group. Some can continue practising the exercises facing the barre while others can perform the exercises without external support.

When a new movement is at first introduced by demonstration of it, it should then be practiced separately in one direction only, following directions given in the “execution” column. Only when the principles of the movement are understood and successfully performed by the participants in one direction, for example to the front, the other directions are then introduced and new challenges are discussed. Then, the sequence may be introduced. An example of the basic sequence is given in table 5. The sequence should be at first performed to counting and later to the music. Clear short verbal instructions are required to remind the participants of the pattern of the sequence at the beginning of learning. Later the members of the group are encouraged to memorize the sequence (adding cognitive task) (Jones & Rose 2005, 289-293).

Exercises should be introduced gradually in a progression from easier to the more demanding ones following the order given in table 5. Once the exercise is performed successfully, the next movement can be introduced. Each sequence can then be developed adding complexity to it, for example as suggested in the column “progression”. There are many exercises for one session; therefore, the instructor can skip some of them or introduce them later, which will add to the variety. Further examples of the progression are presented in table 6. Dual- and multiple tasks are achieved by adding cognitive and / or motor tasks to the exercises.

TABLE 6. Examples of the progression of the barre exercises: dual- and multitasks.

<b>Examples of the progression of the barre exercises</b>	
Adding a cognitive tasks	Adding a cognitive and motor tasks
<ul style="list-style-type: none"> <li>▪ Adding rhythm to the exercise / sequence, for example: “execute the exercise to the count of 4”</li> <li>▪ Counting out loud when performing the exercise / sequence</li> <li>▪ Adding music to the exercise / sequence</li> </ul>	<ul style="list-style-type: none"> <li>▪ Repeating an exercise / sequence sideways to the barre, lightly holding onto the barre with one hand. Then turn and repeat the exercise / sequence, holding the barre with the other hand.</li> <li>▪ Repeating an exercise / sequence sideways to the barre, lightly holding the barre with one hand, while simultaneously executing arm’s movements (for example, using the ballet arms’ positions shown in <b>picture 1</b>, opening to different directions,</li> </ul>

	<p>opening arms in reciprocal movement (functional)</p> <ul style="list-style-type: none"> <li>▪ Repeating an exercise or sequence without the support of the bar first without movement of the arms and then with the movements of the arms</li> <li>▪ Adding a head movement to the exercise / sequence. For example: <ul style="list-style-type: none"> <li>➤ follow fingers of the moving arm with the eyes;</li> <li>➤ turn the head sideways when performing a leg movement to the side.</li> </ul> </li> <li>▪ Adding complexity to the sequence, for example adding a pause: instead of 8 repetitions, perform 6 repetitions of an exercise, then pause and count the time it would take to do the missing 2 repetitions. Then continue to the other direction, using this pattern.</li> <li>▪ Combine the exercises in one sequence, for example: execute 2 battement tendus and battement tendu III in every direction (front, to the side, back and to the side)</li> </ul>
--	--

#### 6.4.7 Summary of principles of manipulating sensory systems during exercises

**Vision:** encourage gaze fixation on a specific target in space while performing exercises, which challenge postural control during standing and moving. Perform exercises standing on the foam.

**Somatosensory:** discourage looking at the feet when learning and practicing exercises, rather encourage verbal expression of how the position or exercise feels. Even though it is not traditional to ballet training, exercises with eyes closed or wearing sunglasses could be done to additionally challenge proprioception.

**Vestibular:** move the head and engage the eyes in the second task, like following hand with eyes. Exercises which are done quickly for example in vertical line, like jumps, challenge the vestibular system. (Jones & Rose 2005, 221-222.)



#### **6.4.8 Practical tips and suggestions for introducing the ballet exercises to older adults**

I suggest to use different exercises to activate tactile feedback of the feet at the beginning of each session, for example exercises such as rolling a soft ball under the sole of the foot. Warm up should be done wearing shoes appropriate for exercise to prevent slipping. However, the ballet exercises must be performed bare foot or wearing socks to increase tactile input, proprioceptive feedback and allow the foot to move freely. Prior to exercises, limits of stability should be explored and moving strategies should be presented and encouraged to apply whenever needed.

If required, the ballet exercises can be partially done sitting either on a chair or on the floor on top of a mat. I also suggest use of the round-shaped mats. This allows to ensure sufficient space around each member of the group and to help them to explore the limits of stability. It can also provide an additional tactile feedback when executing the ballet exercises and prevents slipping on the floor. In many exercises which require extending the leg the whole length, the mats can also help to assist the learning process of ballet exercises.

#### **6.5 Methods, process description and schedule of the thesis**

The process of the thesis is described in the table 7. Here I will shortly outline the most important steps of the working process. The literature search was carried out in PubMed, MedLine, EBSCO and Google Scholar as well as the searches of hardback books in the library. It took a long time to collect information for the theoretical background of the study. There was no shortage of the sources on balance and postural control since a vast amount of researches have been conducted on these topics in the past decades. However, even though the articles about the postural control summarized the physiological systems underlying the complex skill of balance, it was not enough to fully understand each of the systems. I felt similarly about the recommendations on fall prevention. They usually briefly explain the reasons why the various components of the balance control should be trained and gave examples of activities which can be performed. Therefore, in order to deepen my own understanding and to spare the reader from wondering, I searched for the articles which would provide the most substantial knowledge for each of the components

of the balance control based on the facts of mechanics, biomechanics, kinesiology, anatomy and physiology. While reading and analyzing all the research, my understanding of the principles of balance, the various recourses of postural control, risk factors for falls and physiological age related changes expanded to a significant extent.

The searching for dance-related research also took a long time, especially because I was personally interested in the topic. All the new research on dance kinesiology and biomechanics was of great interest to me. Therefore, while writing the thesis I became more systematic and organized at searching for information in order to comply with the available time resources.

Even though ballet has a long history and is well-known for successful training of balance control, I was surprised to discover only one research paper on applying ballet training to improve balance and postural control. When I finally started to design the balance programme, I was confronted with a new challenge. I had to examine the ballet training, which I used for most of my life, first as a dance student and later as a dance teacher, from an entirely different point of view. In this regard, it helped to prioritize the essential goals of the physiotherapy practice, which are based on evidence based practice and functional requirements.

TABLE 7 The process of writing the thesis

November 2014.	Work practice in the health care center and developing idea for the thesis.
Winter - spring 2015	Searching, collecting and analyzing the literature about balance, postural control, balance training interventions for older adults, dance interventions for older adults
June 2015	Submission of the thesis plan
July 2015	Writing the theoretical background of the study and defining limits of the study
August 2015	Designing the balance training programme. Finalizing the study.
October 2015	Presenting the study

## 7 DISCUSSION

The purpose of this study was to build theoretical and practical grounds for a balance training programme for older adults comprised of ballet exercises. The study resulted in materials for a balance training programme grounded on the current literature on balance control, physiologic changes in balance control associated with aging and strategies of balance control used in ballet training. In addition, the programme is based on the basic principles of exercise physiology such as specificity, progression and individuality. Thus, the study is specific to the function of various systems of postural control as well as to balance performance during standing and walking. These systems are required for daily activity. The principle of progression is consistent in each exercise as well as throughout the whole training session. The principle of individuality, which means modifying the exercises for the various levels of the group members, is achieved by a description of different options for each exercise.

The programme offers multimodal training for the older adults: it directly incorporates the elements of strength training, mobility, agility, body awareness and dual and multi-tasking. Moreover, the exercises used in the programme are both challenging and safe to perform, which is essential for older adults with balance impairments. Finally, the programme is innovative. It contributes not only to the older adults' functional goals but also to their learning experiences, their motivation and wider possibilities for participation.

For the physiotherapists, this material offers guidelines for building an alternative balance training programme for older adults. The selected ballet exercises are specific to the functional postural control requirements of daily life. The exercises are described in detail and also introduced in pictures. The instructions include the goals of exercises and warnings about possible mistakes in order to make them easier to teach. The provided examples on how the exercises could be developed and combined also allow the physiotherapist to create balance training he / she would feel comfortable with. In addition, the material provides the principles underlying the structure of each session while flexibility to physiotherapists to adjust or modify the exercises according to the needs of the participants.

To the best of my knowledge, there are no published studies on this topic. The few studies using ballet exercise as an intervention for older adults either contain little of practical

material on the exercises used and principles of training, or they focus on other issues than balance (Creighton & Fisher 2004; Houston & McGill, 2012). However, there are multiple studies on balance training for older adults. They emphasize the importance of a systematic approach to the design of the balance training programme. The main principles highlighted in these studies are the specificity of exercises to the balance function, complying with the principles of basic exercise and incorporating a dual- and multi-task component into the training (Oddsson, Boissy & Melzer 2007; Halvarsson, Franzén & Ståhle 2014). Therefore, this study takes the balance training yet one step further. In addition to the above described principles, it incorporates practice from another field, which is widely researched in its contribution to balance control and also adapts the practice to the purposes of physiotherapy. As a result, it may serve as a motivating tool for both the instructor and participants. Furthermore, integrating ballet, other artistic fields or sports with physiotherapy may assist in achieving two of the important goals of the physiotherapy: encouraging the patients to lead more active lifestyles and allows participation to the patients with health deficit (WCPT 2014).

The limitations of this material for balance training programme are the lack of practical application, lack of participants' education on subjects such as fear of falling and falling prevention strategies and absence of consideration in the presence of various medical conditions. Ideally, the balance training programme should have been piloted on the group of older adults with balance deficit. That would allow for the necessary adjustments to the choice of exercises. Also, this study does not include a discussion component with potential participants, which would directly address the fear of falling and fall prevention. That is, however, an essential part of the training, since the group members' own experiences and concerns could have been addressed and incorporated directly as a part of the balance training. Finally, working with a group of older adults will probably require doing modifications and safety-related precautions to the balance training according to the members' various medical conditions, such as cardiovascular and musculoskeletal conditions, pulmonary disorders, osteoporosis, diabetes and neurological conditions such as Parkinson's disease.

Another important topic, which was not covered in this study is the use of music with the ballet exercises. Music is a necessary part of ballet training, which provides rhythm and required tempo and character. It helps to organize the group to move in unison and serves as a motivational tool for learning. In balance training, music also challenges participants'

cognitive resources. It is possible to buy ready-to-use music for ballet classes. However, the physiotherapists, who will apply the materials from this study, should also become familiar with the correct use of music to accompany the ballet exercises.

The aforementioned issues of testing an implementation of the plan, exploring participant fears, accounting for participants' medical conditions, and use of music are all interesting issues for further research.

## REFERENCES

- Baker, M. K., Atlantis, E. & Singh, M. A. F. 2007. Multi-modal exercise programs for older adults. *Age and ageing*, 36(4), 375-381.
- Bandy, W. D. & Sanders, B. (Eds.). 2007. *Therapeutic exercise for physical therapist assistants*. Lippincott Williams & Wilkins.
- Batson, G. 2010. Feasibility of an intensive trial of modern dance for adults with Parkinson Disease. *Complementary Health Practice Review*, 15, 65–83.
- Beauchet, O., Annweiler, C., Dubost, V., Allali, G., Kressig, R. W., Bridenbaugh, Berrut, G., Assal, F. & Herrmann, F. R. 2009. Stops walking when talking: a predictor of falls in older adults? *European Journal of Neurology*, 16(7), 786-795.
- Bell F. 1998. *Principles of mechanics and biomechanics*. Cheltenham: Stanley Thornes.
- Bläsing, B., Calvo-Merino, B., Cross, E. S., Jola, C., Honisch, J., & Stevens, C. J. 2012. Neurocognitive control in dance perception and performance. *Acta psychologica*, 139(2), 300-308.
- Bowling, A. 1989. Injuries to dancers: prevalence, treatment, and perceptions of causes. *BMJ*, 298(6675), 731-734. Read 21.8.2015. <http://www.bmj.com/content/298/6675/731.full.pdf+html>
- Clippinger, K. S. 2007. *Dance anatomy and kinesiology*. Human Kinetics.
- Connolly, M. & Redding, E. 2010. *Dancing Towards Well-Being in the Third Age: Literature Review on the Impact of Dance on the Health and Well-Being of Older People*. Read 18.6.2015. <http://www.trinitylaban.ac.uk/media/315435/literature%20review%20impact%20of%20dance%20elderly%20populations%20final%20draft%20with%20logos.pdf>
- Costa, M. S. D. S., Ferreira, A. D. S., & Felicio, L. R. 2013. Static and dynamic balance in ballet dancers: a literature review. *Fisioterapia e Pesquisa*, 20(3), 299-305.
- Creighton, B. A., & Fisher, M. M. 2004. Effects of ballet training on muscular endurance and balance in older adults. In *research quarterly for exercise and sport*. Vol. 75, no. 1, pp. A8-a8. 1900 association drive, reston, va 22091 usa: amer alliance health phys educ rec & dance.
- Cullen, K. & Sadeghi, S Vestibular system. 2008. Scholarpedia. Read 28.7.2015. [http://www.scholarpedia.org/article/Vestibular\\_system](http://www.scholarpedia.org/article/Vestibular_system)
- Federici A., Bellagamba, S. & Rocchi M.B. Does Dance Based Training Improve Balance in Adult and Young Old Subjects? A pilot randomized controlled trial. 2005. *Aging Clinical and Experimental Research*. Pub Med.

- Halvarsson, A., Dohrn, M. & Stähle, A. 2014. Taking balance training for older adults one step further: the rationale for and a description of a proven balance training programme. *Clinical rehabilitation*, 0269215514546770.
- Herdman, S. J. & Clendaniel, R. A. 2014. *Vestibular Rehabilitation* (4th Edition). Philadelphia, PA, USA: F. A. Davis. ProQuest ebrary. Read 22.7.2015.
- Hodges, P. W. & Richardson, C. A. 1997. Relationship between limb movement speed and associated contraction of the trunk muscles. *Ergonomics*, 40(11), 1220-1230.
- Horak, F. B. 1987. Clinical measurement of postural control in adults. *Physical therapy*, 67(12), 1881-1885.
- Horak, F. B. 1997. Clinical assessment of balance disorders. *Gait & Posture*, 6(1), 76-84.
- Horak, F. B. 2006. Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? *Age and ageing*, 35, no suppl 2, ii7-ii11.
- Horak, F.B., Henry, S.M. & Shumway-Cook, A. 2007. Postural Perturbations: New Insights for Treatment of Balance Disorders. *Physical therapy*. Read 24.6.2015. <http://ptjournal.apta.org/content/77/5/517>
- Horak, F. B., Wrisley, D. M. & Frank, J. 2009. The Balance Evaluation Systems Test (BESTest) to Differentiate Balance Deficits. *Physical Therapy*, 89(5), 484–498. <http://doi.org/10.2522/ptj.20080071>
- Houston, S. & McGill, A. A mixed-methods study into ballet for people living with Parkinson's. 2013. PubMed. Read 17.6.2015 <http://www.ncbi.nlm.nih.gov.elib.tamk.fi/pmc/articles/PMC3687249/>
- Hugel, F., Cadopi, M., Kohler, F. & Perrin, P. 1999. Postural control of ballet dancers: a specific use of visual input for artistic purposes. *International journal of sports medicine*, 20(2), 86-92.
- Hui, E., Chui, B. T. K. & Woo, J. 2009. Effects of dance on physical and psychological well-being in older persons. *Archives of gerontology and geriatrics*, 49(1), e45-e50.
- Jacobs, J. V. & Horak, F. B. 2007. Cortical control of postural responses. *Journal of neural transmission*, 114(10), 1339-1348.
- Jones, C.J. & Rose, J.R. 2005. *Physical Activity Instruction of Older Adults*. Human kinematics.
- Karinkanta, S., Heinonen, A., Sievänen, H., Uusi-Rasi, K., Pasanen, M., Ojala, K., Fogelholm, M. & Kannus, P. (2007). A multi-component exercise regimen to prevent functional decline and bone fragility in home-dwelling elderly women: randomized, controlled trial. *Osteoporosis International*, 18(4), 453-462.
- Kaatumisten ja kaatumisvammojen ehkäisyn fysioterapiasuositus (Recommendation in physiotherapy on the prevention of falls and falls injuries). 2011. [Online publication]. Suomen fysioterapeutit (Finland's Physiotherapists). [Ref. 28.2.2012]. Read 10.8.2015.

[http://www.suomenfysioterapeutit.fi/images/stories/Liitteet/Fysioterapiasuositus3\\_www.pdf](http://www.suomenfysioterapeutit.fi/images/stories/Liitteet/Fysioterapiasuositus3_www.pdf)

Kell, C. & van Deursen, R. W. M. 2005. Posture and Balance. In: M. Trew & T. Everett (ed.) *Human Movement: An Introductory Text*. Fifth edition. Edinburgh: Elsevier Ltd, 231–253.

Keogh JW, Kilding A, Pidgeon P, Ashley L, Gillis D. 2009. Physical benefits of dancing for healthy older adults: A review. *Journal of Aging and Physical Activity*. 17:479 – 500.

Koutedakis, Y. & Jamurtas, A. 2007. The dancer as a performing athlete: physiological considerations. *Medical problems of performing artists* (vol. 22, no. 1, pp. 32-32). Read 29.6.2015.

<http://wlv.openrepository.com/wlv/bitstream/2436/7196/1/The%20Dancer%20as%20a%20Performing%20Athlete%20.pdf>

Kushner, S., Saboe, L., Reid, D., Penrose, T., & Grace, M. 1990. Relationship of turnout to hip abduction in professional ballet dancers. *The American journal of sports medicine*, 18(3), 286-291.

Martinez, B. R, Curtolo, M, Lucato, A, Yi, L.C. 2014. Balance control, hamstring flexibility and range of motion of the hip rotators in ballet dancers. *European Journal of Physiotherapy* 2014 Dec 16 (4): 212-8.

Menz, H. B., Morris, M. E. & Lord, S. R. 2006. Foot and ankle risk factors for falls in older people: a prospective study. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 61(8), 866-870.

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., Macera, C. A. & Castaneda-Sceppa, C. 2007. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Circulation*, 116(9), 1094.

Oddsson, L. I., Boissy, P. & Melzer, I. 2007. How to improve gait and balance function in elderly individuals—compliance with principles of training. *European Review of Aging and physical activity*, 4(1), 15-23.

O'Sullivan, S. B., Schmitz, T. J. & Fulk, G. 2014. *Physical rehabilitation*. FA Davis.

Pajala, S., Piirtola, M., Karinkanta, S., Mänty, M., Pitkänen, T., Puukallio, A. Sihvonen, S., Kettunen, J. & Kangas, H. 2011. Kaatumisten ja kaatumisvammojen ehkäisyn fysioterapiasuositukset. Read 5.7.2015. [http://www.terveysportti.fi/dtk/sfs/avaa?p\\_artikkeli=sfs00003](http://www.terveysportti.fi/dtk/sfs/avaa?p_artikkeli=sfs00003)

Pajala, S. 2012. Iäkkäiden kaatumisten ehkäisy: IKINÄ-opas (Prevention of Falls in the Elderly: IKINÄ Guidebook). [Online publication]. Helsinki: Terveystien ja hyvinvoinnin laitos (National Institute for Health and Welfare). [Ref. 28.5.2012]. Read 11.8.2015.

<http://www.thl.fi/thl-client/pdfs/923b49af-ca1a-4c44-a14c-505319cac74e>



Paskevskaja, Anna. *Both Sides of the Mirror: The Science and Art of Ballet* (2nd Edition). Hightstown, NJ, USA: Princeton Book Company, 2004. ProQuest ebrary. Read 3.8.2015.

Pedersen, C., Erleben, K., & Sparring, J. 2006. Ballet balance strategies. *Simulation Modelling Practice and Theory*, 14(8), 1135-1142. Read 29.6.2015. [http://curis.ku.dk/ws/files/38552090/1\\_s2.0\\_S1569190X0600061X\\_main.pdf](http://curis.ku.dk/ws/files/38552090/1_s2.0_S1569190X0600061X_main.pdf)

Pollock, A. S., Durward, B. R., Rowe, P. J., & Paul, J. P. 2000. What is balance? *Clinical rehabilitation*, 14(4), 402-406.

Reimann, P. 2011. Design-based research. In *Methodological Choice and Design*. Springer Netherlands.

Sakari-Rantala, R. 2003. Iäkkäiden ihmisten liikunta- ja kuntosaliharjoittelu. *Liikunnan jakansan-terveyden julkaisuja* 142. Jyväskylä: Korpiljyvä Oy.

Schmit, J. M., Regis, D. I., & Riley, M. A. 2005. Dynamic patterns of postural sway in ballet dancers and track athletes. *Experimental Brain Research*, 163(3), 370-378. Read 29.6.2015.

<http://link.springer.com/article/10.1007/s00221-004-2185-6#page-1>

Shanon, L. & Hoffman P. How does the balance system work? American Physical Therapy Association. Section of Neurology.

Sherrington C., Whitney J.C., Lord, S.R., Herbert. R.D., Cumming, R.G. & Close J.C. 2008. Effective exercise for the prevention of falls: a systematic review and meta-analysis. *Journal of the American Geriatric Society*. 56(12):2234-43.

Sherman, A. J., Mayall, E. & Tasker, S. L. 2014. Can a Prescribed Turnout Conditioning Program Reduce the Differential Between Passive and Active Turnout in Pre-professional Dancers? *Journal of Dance Medicine & Science*, 18(4), 159-168.

Shigematsu, R., Chang, M., Yabushita, N., Sakai, T., Nakagaichi. M., Nho, H. & Tanaka, K. 2002. Dance-based aerobic exercise may improve indices of falling risk in older women. *Age Ageing*, 31. PubMed.

<http://www.ncbi.nlm.nih.gov/pubmed/12147563>

Shumway-Cook, A. & Woollacott M.H. 2007. *Motor control: translating research into clinical practice*. 3rd ed. Philadelphia: Lippincott Williams & Wilkins.

Shumway-Cook, A., & Horak, F. B. 1986. Assessing the influence of sensory interaction on balance suggestion from the field. *Physical Therapy*, 66(10), 1548-1550.

Silsupadol, P., Siu K-C., Shumway-Cook, A. & Woollacott M.H. 2006. Training of Balance Under Single- and Dual-Task Conditions in Older Adults With Balance Impairment. *Physical therapy*. Read 24.6.2015. <http://ptjournal.apta.org/content/86/2/269>

Uritani, D., Fukumoto, T., Matsumoto, D. & Shima, M. 2014. Reference values for toe grip strength among Japanese adults aged 20 to 79 years: a cross-sectional study. *Journal of Foot and Ankle Research*, 7, 28. PubMed.

<http://www.ncbi.nlm.nih.gov/pubmed/24855492>

Vaganova, A. I. 1969. Basic principles of classical ballet: Russian ballet technique. Courier Corporation.

Van Camp, J. 2015. Photos for the visual guide of the ballet barre exercises.

Winter, D. A., Patla, A. E. & Frank, J. S. 1990. Assessment of balance control in humans. *Medical Progress through Technology Technol*, 16(1-2), 31-51. Read 29.6.2015. <http://www.castonline.ilstu.edu/McCaw/hpr482/1848%20Winter%201990%20balance.pdf>

Winter, D. A. 1995. Human balance and posture control during standing and walking. *Gait & posture*, 3(4), 193-214.

Wolf, B., Feys, H., De Weerdt, W., van der Meer, J., Noom, M. & Aufdemkampe, G. 2001. Effect of a physical therapeutic intervention for balance problems in the elderly: a single-blind, randomized, controlled multicentre trial. *Clinical Rehabilitation*, 15(6), 624-636. Read 26.6.2015. <http://www.cebp.nl/media/m761.pdf>

Woollacott, M. H. & Tang, P. F. 1997. Balance control during walking in the older adult: research and its implications. *Physical therapy*, 77(6), 646-660.

World Confederation for Physical Therapy. 2014. Policy Statement: Description of physical therapy. London, UK: WCPT. Read 3.12.2014. <http://www.wcpt.org/policy/ps-descriptionPT>

World Confederation for Physical Therapy. 2003. Evidence Based Practice-an over-view. Read 3.12.2014. <http://www.wcpt.org/node/100039>

World Confederation for Physical Therapy. 2014. Policy statement: Description of physical therapy. Read 21.8.2015. <http://www.wcpt.org/policy/ps-descriptionPT>

World Health Organization. 2001. International classification of functioning, disability and health: ICF. World Health Organization. Read 10.8.2015. <http://www.who.int/classifications/icf/en/>