**sensamove** *&***MTS360**

**EN**

*Background &*

*Recommendations*

MNL-BB100614-EN





B&A-170101-EN

# Introduction

**MTS360 LLC**

MTS360 LLC is a company whose purpose is to connect healthcare providers with new, affordable and highly effective medical devices. Our expertise in FDA and ISO regulations, quality assurance system and our exceptional service make us a key partner within the long term relationship with Sensamove. Sensamove has shown its dedication towards providing the healthcare industry with highly versatile medical equipment and with the help of MTS360, Sensamove is sure to make its mark across the U.S. market. The manufacturing and distribution rights of Sensamove products in the U.S. have been granted to MTS360 fostering the start of a great relationship.

## Sensamove

Sensamove is a young, dynamic and innovative company that develops and produces interactive exercise equipment. Sensamove wants to encourage exercising by making it more fun, exciting and its results readily measurable. Our mission is to make balance training more enjoyable and understandable. More fun for your client and transparent for you.

Sensamove offers different measuring & exercising devices with basic and supplementary software packages for improving balance, core stability and coordination. By combining conventional core stability training equipment with sensor technology and biofeedback software, Sensamove provides therapists and users with insight-giving, comprehensible, effective and entertaining exercise tools. The products have an easy-to-understand software user interface and offer both measuring functionality and a challenging gaming environment for body exercises.

In this document you can find information about the application, the target group and the argumentation of the following Sensamove products:

* Sensamove 2D sensor
* Sensamove Miniboard
* Sensamove Cushion
* Sensamove 3D Cervical Trainer



Figure Sensamove Miniboard

Figure 1 Sensamove 2D sensor

Figure 3 Sensamove Cushion

Figure 4 Sensamove Cervical Trainer

Index

[1 Sensamove 2D sensor 6](#_Toc475093184)

[Application 6](#_Toc475093185)

[Basics 6](#_Toc475093186)

[Stability and mobility 6](#_Toc475093187)

[Data quantification 7](#_Toc475093188)

[Games 7](#_Toc475093189)

[Target Group 8](#_Toc475093190)

[Argumentation 8](#_Toc475093191)

[Biofeedback 8](#_Toc475093192)

[Exergaming 8](#_Toc475093193)

[Automating postural control 9](#_Toc475093194)

[2 Sensamove MiniBoard 10](#_Toc475093195)

[Application 10](#_Toc475093196)

[Calibration and starting position 10](#_Toc475093197)

[Mobility and Stability 10](#_Toc475093198)

[Target Group 10](#_Toc475093199)

[Argumentation 10](#_Toc475093200)

[Elderly 11](#_Toc475093201)

[Sports 11](#_Toc475093202)

[Postural control 11](#_Toc475093203)

[3 Sensamove Cushion 13](#_Toc475093204)

[Application 13](#_Toc475093205)

[Calibration and starting position 13](#_Toc475093206)

[Mobility and Stability 13](#_Toc475093207)

[Target Group 13](#_Toc475093208)

[Argumentation 13](#_Toc475093209)

[Postural control 13](#_Toc475093210)

[Sitting posture 14](#_Toc475093211)

[Core Stability 14](#_Toc475093212)

[4 Sensamove 3D Cervical Trainer 15](#_Toc475093213)

[Application 15](#_Toc475093214)

[Calibration and starting position 15](#_Toc475093215)

[Mobility and Stability 16](#_Toc475093216)

[Target Group 16](#_Toc475093217)

[Argumentation 16](#_Toc475093218)

[Postural control 16](#_Toc475093219)

[Cervical Spinal cord stability 16](#_Toc475093220)

[5 References 17](#_Toc475093221)

# 1 Sensamove 2D sensor

The Sensamove 2D sensor is a small attachable sensor module that can be used to encourage exercising by making it more fun and exciting. All Sensamove devices have this sensor build in, but the Sensamove 2D sensor can also be attached to any other balance/tilting device easily, like e.g. Pedalo, MFT or BackApp.

The Sensamove sensor technology and biofeedback software provides therapists and users with insight-giving, comprehensible, effective and entertaining exercise tools. It has an easy-to-understand software user interface and offers both measuring functionality and a challenging gaming environment for body exercises.



Figure 5 Sensamove 2D sensor

## Application

### Basics

In the basic measuring and recording software a red dot on the monitor screen of the connected laptop/PC corresponds exactly to the tilting angle of the balance exercise system in use. As soon as a user is exercising on Sensamove equipment the red dot on the screen will move correspondingly and provide in this way biofeedback on the movements made. This can be used both for diagnostic and therapeutic purposes. Movement of the red dot can be recorded and displayed as green trajectories on the monitor screen.

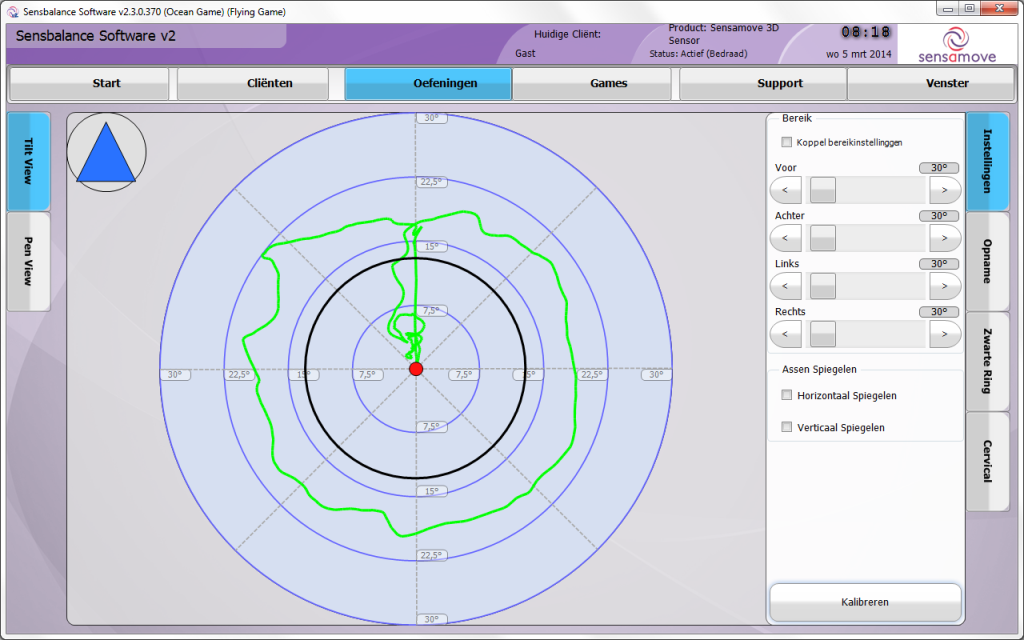


Figure 6 monitor screen with red dot and green trajectories of the recorded movement

### Stability and mobility

The focus of core stability training should be on the integration of local and global stabilizer muscles, which is important to control the neutral joint position (Comerford and Mottram 2001). Isolation of specific muscles or joints should be avoided in core stabilization exercises and the emphasis should be on the training of muscle activation sequences in functional positions and motions (Kibler, Press, and Sciascia 2006).This way, normal biomechanical motions are restored through normal physiological activations. The eventual goal is to make the required muscle recruitment automatic and to achieve an adequate coordination of activation of the segments that are part of the kinetic chain (Kibler, Press, and Sciascia 2006).

As mentioned above stability and proprioceptive training seems to be important for back-related problems, while mobility seems to be more important for postural corrections and for the training of larger muscles. By increasing or decreasing sensor tilt or sensitivity in the software both training types can be easily applied. A large tilt means that larger motions should be made in order to move the cursor on the screen and vice versa for a small tilt value. Large tilt values, where large motions are needed correspond therefore with mobility training, while small tilt values, where fast and small corrections are needed, will result in stability training.

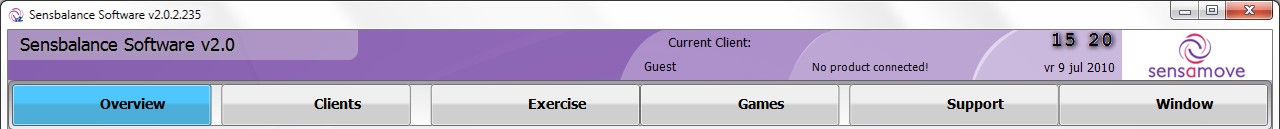
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sensor tilt settings | | | | |
| Mobility | Large tilt | Large motions, | Mobile globalisers | Postural ergonomic training; awareness of joint motion; Large muscle group training; dynamic training |
| Stability | Small tilt | Small motions, fast corrections | Local stabilisers | Back pain related disorders; proprioception training; stability training; static training |

### Data quantification

Sitting and standing balance performance and muscle response times may be good indicators of core stability (Borghuis, Hof, and Lemmink 2008), the software therefore gives indications of aspects of balance like reaction time, proprioceptive, dynamic and static balance and neuromuscular coordination.

### Games

The Sensamove sensor technology and biofeedback software provides not only insight-giving and effective exercise tools for users and therapists, but also encourages exercising by making it more fun and exciting through games. Sensamove has several games especially designed for the Sensamove devices, such as the balance game, the flying game, the ocean game and the farm game. These games can be played by everybody because there are different levels of difficulty. By adapting the sensor sensitivity difficulty can also be set and games can be used to train mobility and stability muscles by adapting sensitivity.



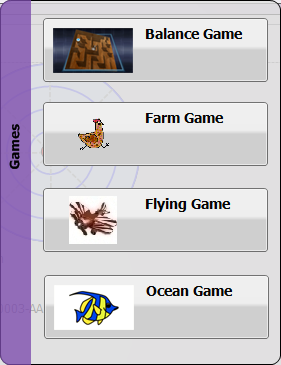


Figure 7 monitor screen with game options



Figure 8 monitor screen during playing balance game

## Target Group

The Sensamove 2D sensor is used in Sensamove devices or can be attached on any other balance/tilting device to train factors like neuromuscular coordination, reaction time, dynamic and static balance and proprioception for athletes and patients with impaired balance or muscle control.

## Argumentation

### Biofeedback

Home based exercise programs are effective but a low adherence to these programs is problematic. Using biofeedback to stimulate exercising contributes to an increasing adherence(Schönauer, Pintaric, Kaufmann, Jansen – Kosterink, & Vollenbroek-Hutten, 2011; [Jansen-Kosterink,](https://ru-on-worldcat-org.ru.idm.oclc.org/search?queryString=au:Jansen-Kosterink%20S.M.&databaseList=2474,3441,2273,2194,1931,1697,2268,3313,2267,3036,638,2507,1978,3012,3374,3450,3250,2437,3448,1941,2237,2236,3049,1982,2795,2233,2375,1164,2175,3384,2294,3382,3218,1953,1875,3018,3336,2005,1674,3378,2443,1672,1834,2221,3155,2264,3551,2462,2262,3197,2261,2260,3195,2977,3548,1842,2259,2897,3225,1847,3429) [Huis In ’T Veld,](https://ru-on-worldcat-org.ru.idm.oclc.org/search?queryString=au:Huis%20In%20&#39;T Veld R.M.H.A.&databaseList=2474,3441,2273,2194,1931,1697,2268,3313,2267,3036,638,2507,1978,3012,3374,3450,3250,2437,3448,1941,2237,2236,3049,1982,2795,2233,2375,1164,2175,3384,2294,3382,3218,1953,1875,3018,3336,2005,1674,3378,2443,1672,1834,2221,3155) [Hermens](https://ru-on-worldcat-org.ru.idm.oclc.org/search?queryString=au:Hermens%20H.J.&databaseList=2474,3441,2273,2194,1931,1697,2268,3313,2267,3036,638,2507,1978,3012,3374,3450,3250,2437,3448,1941,2237,2236,3049,1982,2795,2233,2375,1164,2175,3384,2294,3382,3218,1953,1875,3018,3336,2005,1674,3378,2443,1672,1834,2221,3155,2264,3551,2462,2262,3197,2261,2260,3195,2977,3548,1842,2259,2897,3225,1847,3429) & [Vollenbroe](https://ru-on-worldcat-org.ru.idm.oclc.org/search?queryString=au:Vollenbroek-Hutten%20M.M.R.&databaseList=2474,3441,2273,2194,1931,1697,2268,3313,2267,3036,638,2507,1978,3012,3374,3450,3250,2437,3448,1941,2237,2236,3049,1982,2795,2233,2375,1164,2175,3384,2294,3382,3218,1953,1875,3018,3336,2005,1674,3378,2443,1672,1834,2221,3155,2264,3551,2462,2262,3197,2261,2260,3195,2977,3548,1842,2259,2897,3225,1847,3429)k-Hutten, 2013). The Sensamove software is more than a measurement tool. The software enables to do exercises and play games using biofeedback. Several studies found significantly greater improvements in balance, stability, posture and movement control in patients training with biofeedback compared to the control group (Kent, Laird & Haines, 2015; [Kim,](https://ru-on-worldcat-org.ru.idm.oclc.org/search?queryString=au:Kim%20S.-J.&databaseList=2474,3441,2273,2194,1931,1697,2268,3313,2267,3036,638,2507,1978,3012,3374,3450,3250,2437,3448,1941,2237,2236,3049,1982,2795,2233,2375,1164,2175,3384,2294,3382,3218,1953,1875,3018,3336,2005,1674,3378,2443,1672,1834,2221,3155,2264,3551,2462,2262,3197,2261,2260,3195,2977,3548,1842,2259,2897,3225,1847,3429) [Kim,](https://ru-on-worldcat-org.ru.idm.oclc.org/search?queryString=au:Kim%20K.-H.&databaseList=2474,3441,2273,2194,1931,1697,2268,3313,2267,3036,638,2507,1978,3012,3374,3450,3250,2437,3448,1941,2237,2236,3049,1982,2795,2233,2375,1164,2175,3384,2294,3382,3218,1953,1875,3018,3336,2005,1674,3378,2443,1672,1834,2221,3155,2264,3551,2462,2262,3197,2261,2260,3195,2977,3548,1842,2259,2897,3225,1847,3429) [Lee,](https://ru-on-worldcat-org.ru.idm.oclc.org/search?queryString=au:Lee%20S.-M.&databaseList=2474,3441,2273,2194,1931,1697,2268,3313,2267,3036,638,2507,1978,3012,3374,3450,3250,2437,3448,1941,2237,2236,3049,1982,2795,2233,2375,1164,2175,3384,2294,3382,3218,1953,1875,3018,3336,2005,1674,3378,2443,1672,1834,2221,3155,2264,3551,2462,2262,3197,2261,2260,3195,2977,3548,1842,2259,2897,3225,1847,3429) & [Cho](https://ru-on-worldcat-org.ru.idm.oclc.org/search?queryString=au:Cho%20H.-Y.&databaseList=2474,3441,2273,2194,1931,1697,2268,3313,2267,3036,638,2507,1978,3012,3374,3450,3250,2437,3448,1941,2237,2236,3049,1982,2795,2233,2375,1164,2175,3384,2294,3382,3218,1953,1875,3018,3336,2005,1674,3378,2443,1672,1834,2221,3155,2264,3551,2462,2262,3197,2261,2260,3195,2977,3548,1842,2259,2897,3225,1847,3429), 2016; Yang, 2016). Taube et al. (2008) found decreases in body sway using a laser pointer as biofeedback. Sihvonen et al.(2004-2) found improved dynamic balance when giving visual feedback and Bisson et al.(2007) found decreased reaction time. Visual feedback seems especially important in dynamic balance tasks (Sihvonen et al., 2004-1) and in static balance tasks while standing on one leg (Hazime et al. 2012). With feedback elderly and young adults move more rhythmic, on a controlled manner and more accurate with large motions during exercise conditions compared to normal therapeutic interventions, what is even more promoted during exergaming (Lamoth, Caljouw, and Postema 2011). Younger people may benefit from cursor trace and increased visual feedback (Lamoth, Caljouw, and Postema 2011; Rougier 2005). In the elderly, feedback results also in positive effects for fluency and accuracy but they may experience difficulties in incorporate extra feedback possibilities such as visual gain and cursor trace (Lamoth, Caljouw, and Postema 2011). Those additional feedback possibilities may therefore be used to improve or discriminate automation of stability capabilities.

### Exergaming

Interactivity and motivation are the major advantages of serious gaming. Participants are motivated to exercise (Jansen-Kosterink et al.,2013; Burdea, 2003), enjoy training (Schönauer et al., 2011) and improve condition (Jansen-Kosterink et al.,2013) and motor skills (Schönauer et al., 2011; Jansen-Kosterink et al.,2013). For all ages exercise game based therapy seems to motivate clients because of the challenge and the pleasant manner of learning (Lamoth, Caljouw, and Postema 2011). A greater level of interest and enjoyment was shown in participants in the exergaming group compared to a conventional exercise group who trained posture on a wobble board (Fitzgerald, Trakarnratanakul, Smyth & Caulfield, 2010). Also children demonstrated better movement, better control and reported greater interest in doing a serious game exercise compared to a conventional exercise ([Bryanton et al.,](https://ru-on-worldcat-org.ru.idm.oclc.org/search?queryString=au:Bryanton%20C&databaseList=2474,3441,2273,2194,1931,1697,2268,3313,2267,3036,638,2507,1978,3012,3374,3450,3250,2437,3448,1941,2237,2236,3049,1982,2795,2233,2375,1164,2175,3384,2294,3382,3218,1953,1875,3018,3336,2005,1674,3378,2443,1672,1834,2221,3155,2264,3551,2462,2262,3197,2261,2260,3195,2977,3548,1842,2259,2897,3225,1847,3429) 2006).

Another advantage of exergaming as mentioned above, is that users will move more rhythmic, on a controlled manner and move more accurate with large motions during exercise conditions compared to normal therapeutic interventions, or even compared to comparable computer based exercises with visual feedback (Lamoth, Caljouw, and Postema 2011).

### Automating postural control

Data from Bisson et al., (Bisson et al. 2007) suggest seniors were able to automate a postural task as a result of biofeedback training and virtual reality training. The previous studies (Lamoth, Caljouw, and Postema 2011) where users moved more fluent and accurate strengthens this finding. Automating postural control is critical in an older adult’s life because seniors need more attention for any postural task, as they get older. In fact, it has been demonstrated that reaction time is one of the most important factors to predict a fall. Since attention resources are limited, automating a task helps free the individual’s processing capacity to focus on other tasks.

# 2 Sensamove MiniBoard

The Sensamove MiniBoard is an unstable wobble board where tilt is measured with the Sensamove 2D sensor. The sensor is connected to the computer and on the monitor of the connected laptop direct visual feedback is presented about the exercises performed by ankle, knee and core. With easy exchangeable accessories the tilting angle and exercise difficulty can be customized. This makes the Miniboard a widely applicable training and therapy tool.

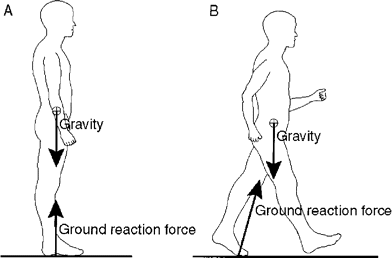


Figure 9 Sensamove Miniboard

## Application

### Calibration and starting position

A good calibration is necessary for correct biofeedback. The Miniboard must be calibrated before standing on top of it. The right starting position is with a straightened back, feet shoulder width apart, knees not locked but also not bended, pelvis in a neutral position and the chin retracted slightly. Weight should be divided equally on both feet.



Ground reaction force

Body center of gravity

Figure 10 Body center of gravity vertically located to ground reaction force

For adults it is recommended to position the foot above the centerline of the board. Markers indicate the centerline on the MiniBoard. The malleolus is then positioned at the height of line 2 on the MiniBoard. The ground reaction force is then vertically located to the body center of gravity (fig.10). The position of the feet can be adjusted on basis of the exercise goal. Feet can be positioned less wide apart to make exercises more difficult or wider apart to make exercises easier.

### Mobility and Stability

When the intervention should be directed on postural improvements mobility should be measured and trained. On the other hand with balance related deficits or problems stability should be measured and trained.

## Target Group

The Sensamove MiniBoard is a tool to measure and train factors like neuromuscular coordination, reaction time, dynamic and static balance and proprioception for athletes and patients with impaired balance among other, diabetes, cerebral palsy, DCD, Parkinson and stroke patients. It can also be used to improve standing posture ergonomics, as a fall prevention tool in elderly and as injury prevention or recovery tool of lower extremity. Additionally, the MiniBoard is particularly suitable for exercising with children.

## Argumentation

Wobble board exercise training is commonly recommended for sport specific training, knee (Caraff

a et al. 1996; Garrick and Requa 2005) or ankle (van der Wees et al. 2006) injury prevention and injury recovery (Marini et al. 2008; Wester et al. 1996, 1998). Furthermore, wobble board exercise is effective for fall prevention (S. Sihvonen et al. 2004 -1) or for individuals with balance deficits and for balance training for patients with central nervous system dysfunction (Prosperini et al. 2010) such as as stroke, spinal cord injury, Parkinson and multiple sclerosis. Wobble board training is effective in improving static and dynamic balance among healthy adolescents (Emery et al. 2005) as in elderly or e.g. stroke survivors (Onigbinde, Awotidebe, and Awosika 2009) or diabetes patients. Diabetes patients often have neuropathy with symptoms such as pain, tingling, or loss of feeling in the hands, arms, feet, and legs. This group benefits from balance training using a wobbling board with emphasis on the anterior-posterior neuromuscular elements of stability (Akbari et al. 2012).

One of the main benefits of wobble board training is the improvements in proprioception (Caraffa et al. 1996; Hupperets, Verhagen, and Mechelen 2009; Prosperini et al. 2010), and consequently greater improvement in ankle inversion movement discrimination is found (Waddington and Adams 2004). Furthermore, symmetry of weight distribution was improved using wobble board training (Adedoyin et al. 2008).

### Elderly

Muscle weakness is found to be a consistent risk factor for falls in the elderly (Horlings et al. 2008). One of the problems of aging is the decrease in postural control leading to decreased balance capabilities (Liaw et al. 2009; Sturnieks, St George, and Lord 2008). Both elderly and young adults provided from the Miniboard training where, young adults move faster, more consistent, more stable and with less deviation compared to elderly (Lamoth, Caljouw, and Postema 2011). Training on a wobbling board has been proved to be an effective way to improve balance tasks. Especially elderly showed balance improvements measured by foam standing, and they were able to increase their centre of mass displacement or reach distance (Ogaya et al. 2011)

### Sports

Sports containing a high degree of pivoting or direction changes, as well as rapid acceleration and deceleration manoeuvres like basketball, soccer, volleyball and handball, wobble board training is suggested for injury prevention (Emery et al. 2005). Resistance training on a wobble board applied with lower forces resulted in similar strength improvements with untrained young individuals compared to stable machines employed heavier loads (Sparkes and Behm 2010). Furthermore, better hockey skating speed was correlated with wobble board balance tests performance (Behm et al. 2005).

Postural control  
Balance measurement will help to identify poor standing postural control but also to differentiate static vestibular deficits from dynamic and mechanical factors that contribute to the patient’s gait disorder and thus, can guide treatment (Rose et al. 2002).

About 20% of all children and adolescents in countries of the World Health Organization (WHO) European Region are overweight, including one third affected by obesity (Branca, Nikogosian, and Lobstein 2007). Being overweight or obese was found to be detrimental for fine motor skill performance in the standing on small base of support conditions, which confirms the postural control difficulties observed in overweight and obese children (Wagner et al. 2011). Additionally, obese participants also produced lower scores in the sitting condition. In sitting tasks complexity of postural organization is decreased and therefore, researchers concluded that obese children might suffer from underlying perceptual-motor coordination difficulties (Wagner et al. 2011). Obesity is found to be detrimental for a (task and gender speciﬁc) consolidation of severe developmental coordination disorder (DCD) even beyond childhood (Wagner et al. 2011). A relation was found between body weight and postural stability with adult males (Hue et al. 2007). This leads to the concluding importance of balance training for coordination, stability and postural control for children with starting overweight in dynamic and static conditions.

Motor control and the onset of gait is often delayed in children with cerebral palsy and this may influence further development of postural control (Rose et al. 2002). Normally those children show little improvement in balance control by maturing. Also the type of surgical treatment may have large impact on their balance capabilities, mainly the effect on balance of hamstring lengthening operations should get special attention (Rose et al. 2002).

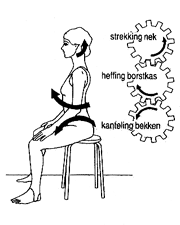
# 3 Sensamove Cushion

The Sensamove Therapy Cushion is an air filled cushion with a sensor mounted on it. The sensor is connected to the computer and on the monitor of the connected laptop direct visual feedback is presented of pelvis tilt and the consequent spine erection and lumbar lordosis or kyphosis.



Figure 11 Sensamove Cushion

## Application



Figuur 12 Correct sitting starting position

### Calibration and starting position

A good starting position is necessary for correct calibration. A proper starting position is when the knees are bended in a 90 to 110-degree angle with both feet flat on the floor. The pelvis is tilted slightly to stimulate the correct S-curve of the spinal cord. The next step is to straightened the spine and retracted the chin slightly. The shoulders should be relaxed, in line with the hips and the hands are relaxed positioned on the knees. Now the calibration button can be clicked and the exercise or game can be started.

### Mobility and Stability

When the intervention should be directed on postural improvements mobility should be measured and trained. On the other hand, with balance related deficits or problems stability should be measured and trained.

## Target Group

The Sensbalance Therapy Cushion can be used to measure and train factors like neuromuscular coordination, reaction time, dynamic and static balance and proprioception for among other athletes and patients with impaired balance. It can also be used to improve posture ergonomics or to avoid and recover from low back injuries and pain. Additionally, the cushion is particularly suitable for exercising with children.

## Argumentation

### Postural control

It has been shown that maintaining a stable postural orientation is a requisite for many daily activities, including accurate upper limb movements (i.e. catching, reaching and grabbing but also walking, biking). Obese patients’ fine motor skill performance is worse compared normal weight counterparts, during standing but when seated as well (Wagner et al. 2011). As reported by users and confirmed by literature findings (Davids et al. 2000; Savelsbergh et al. 2005) postural control while seated is less demanding and therefore results in better balance performances and consequently success experiences. Which is especially of important for children with impaired balance control (i.e. overweight, DCD, CP).

### Sitting posture

Low back pain is one of the most common problems seen with desktop workers. Often low back pain can be prevented or decreased by improving sitting posture. Normally while sitting, the pelvis rotates backwards, and lumbar lordosis is flattened which increases load on the intervertebral discs and spine (Watanabe et al. 2008). Sitting in a slumped position is known to increase disc pressure even more, and to aggravate chronic low back pain (Watanabe et al. 2008). By tilting the pelvis, the spine straightens and therefore awareness of how to tilt the pelvis plays a crucial role in good sitting posture.

### Core Stability

Low back pain is found to be related to spinal instability (Arokoski et al. 2001). Spinal instability can lead to excessive tissue strain and consequent low back pain (Arokoski et al. 2001). Spinal instability can be the result of dysfunction of spinal structures, dysfunction of trunk muscles or neuromuscular deficits (Borghuis, Hof, and Lemmink 2008; Zazulak et al. 2007). For example direction-specific muscle activations are important in providing core stability, particularly when encountering sudden perturbations (Borghuis, Hof, and Lemmink 2008). Low back pain associated factors like; poor muscle endurance, altered muscle firing rates and muscular imbalance deficits, are suggested to be caused by proprioceptive impairments (Akuthota and Nadler 2004; Borghuis, Hof, and Lemmink 2008). Proprioception plays a key role in direction specific muscle activation. This explains why patients with low back pain or muscle stiffness often have difficulty in fluently rotate lumber disks and could benefit from training on the Cushion, which provides direct feedback and therefore promotes implicit postural learning. Sitting balance performance and trunk muscle response times are therefore suggested to be good indicators of core stability (Borghuis, Hof, and Lemmink 2008). Furthermore, athletes with a history of low back pain continued to demonstrate motor control deficits of the trunk, even after clinical recovery and return to their prior level of competition (Zazulak et al. 2007).

# 4 Sensamove 3D Cervical Trainer

The Sensamove 3D Cervical Trainer is an innovative registration product for motion feedback and practicing head movements playfully. One can train head movements to increase muscle strength, coordination and stability in several predetermined exercises and games. The Cervical Trainer consists of a 3D senscoordination sensor, the latest 3D sensor technology and basic software. The product is worn with an adjustable headband and measures spatial movements.



Figure 13 Sensamove Cervical Trainer

## Application

### http://snipwonen.nl/temp/www.snipwonen.nl/uploaded/Ergonomie/fig_07.gifCalibration and starting position

A good starting position is necessary for correct calibration. A proper starting position is when the knees are bended in a 90 to 110-degree angle with both feet flat on the floor. The pelvis is tilted slightly to stimulate the correct S-curve of the spinal cord. The next step is to straightened the spine and retracted the chin slightly. The shoulders should be relaxed, in line with the hips and the hands are relaxed positioned on the knees. Now the calibration button can be clicked and the exercise or game can be started.

The 3-dimensional head movements are represented in two views: a Tilt view and a Pen view. Because of these two view-options movements of the head can be measured in craniocervical flection and extension, lateral flection, rotation and the product can be used as biofeedback device for protraction and retraction exercising.

Figuur 14 Correct sitting starting position

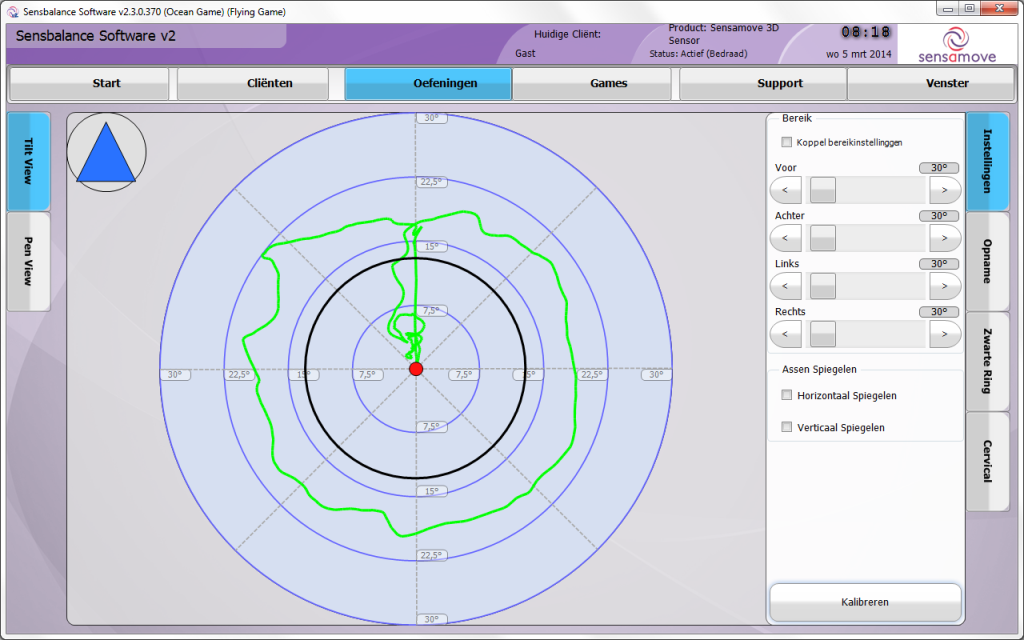
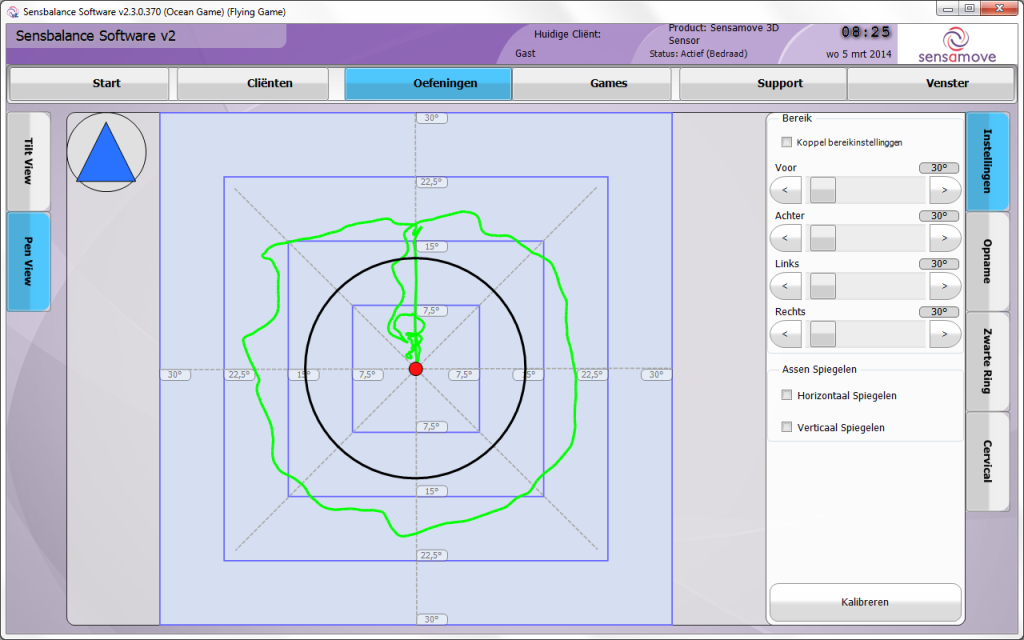


Figure 16 Monitor recording in Tilt view

Figure 15 Monitor recording in Pen view

### Mobility and Stability

When the intervention should be directed on stiffness or/and neck pain decrease mobility should be measured and trained. On the other hand, with balance related deficits or problems stability should be measured and trained.

## Target Group

The Sensamove 3D Cervical Trainer can be used to measure and train factors like neuromuscular coordination, reaction time, dynamic and static balance and proprioception for patients with impaired balance in the cervical region, to improve cervical posture or to avoid and recover from neck injuries and pain. In specially the 3D Cervical Trainer can easily determine Range of Motion (ROM) and Joint Position Error (JPE).

## Argumentation

### Postural control

Neck disorders remain a common problem in modern, industrialized countries. (Ylinen et al., 2003) Neck pain is a frequent reason for consultation a physician (Elbinoune et al., 2016; Lee & Kim, 2016). The symptoms of patients with neck problems are among other things pain, stiffness, and limited range of motion (ROM) (Lee & Kim, 2016).

Cervical muscle dysfunction may be the reason for neck pain. (Cheng, Chen, Kuo, Wang, 2010; Nederhand, IJzerman, Hermens, Baten & Zilvold, 2000). Researchers have found that with regard to the postural control system, people with neck pain have demonstrated altered proprioception (may be due to atrophied muscles (Fejer et al., 2004; Paulus & Brugmagne, 2008)), balance disturbances and altered postural activity of cervical muscles (Fejer et al., 2004; Paulus & Brugmagne, 2008; Jull, Falla, Treleaven, Hodges & Vicenzino, 2005). Cervical joint position error (JPE) is useful to test proprioception function (Jull et al., 2005). Abnormal cervical joint position error has been detected in patients with neck pain using either tests of ability to relocate the natural head posture after an active movement or to actively relocate a position within a movement plane (Jull et al., 2005). Specific exercise programs for proprioception function have been shown to improve joint position error as well as a decrease in neck pain. These exercise programs activate the suboccipital muscles (Jull et al., 2005). The 3D Cervical Trainer enables exercises and games to train proprioception function. Patients have to repeat a task first with and then without biofeedback. The software for the Cervical Trainer has been specially developed to train the deep suboccipital and flexor muscles to improve patient’s proprioception, balance and postural activity of cervical muscles.

### Cervical Spinal cord stability

Individuals with neck pain have an inferior ability to increase and hold progressively inner range positions of craniocervical ﬂexion (Falla, Jull & Hodges, 2003). Several studies have shown that cervical muscle function training may be a beneficial intervention for the management of patients with neck pain (Cheng et al., 2010; O’Leary, Falla, Ellioit & Jull, 2009; Jull, Falla, Vicenzino & Hodges, 2008; O’Leary, Falla, Hodges, Jull & Vicenzino, 2006; Fejer, Ohm Kyvik & Hartvigsen, 2004). Patients with spinal instability will also benefit from muscle function training because spinal stability was found to be more significantly affected by muscle dysfunction than by disc degeneration (Cheng et al., 2010). There is a preference for low muscle strain exercises focused on stability, muscle control and coordination instead of strength training for neck pain patients(Jull et al., 2008; O’Leary, Falla, Hodges, Jull & Vicenzino, 2006). Training of the deep neck flexors was found effective (Jull et al., 2008; O’Leary, Falla, Hodges, Jull & Vicenzino, 2006) compared to self-exercise in patients with neck pain (Lee & Kim, 2016). In addition to measuring ROM and JPE, the Cervical Trainer is ideally suited to train stability, muscle control and coordination. Different exercises and games train different movements and by setting the sensitivity the degree of muscle attraction and control can be managed. The more sensitivity is set, the smaller the movements have to be, the more muscle control and coordination is needed to complete the exercise or game properly.

# 5 References

Adedoyin, Rufus A et al. 2008. “Effects of wobble board training on weight distribution on the lower extremities of sedentary subjects.” 16: 247-253.

Akbari, Mohammad et al. 2012. “Do diabetic neuropathy patients benefit from balance training?” *Journal of rehabilitation research and development* 49(2): 333-8. http://www.ncbi.nlm.nih.gov/pubmed/22773533.

Akuthota, Venu, and Scott F Nadler. 2004. “Core strengthening.” *Archives of Physical Medicine and Rehabilitation* 85(March): 86-92. http://linkinghub.elsevier.com/retrieve/pii/S0003999303012358 (Accessed July 13, 2012).

Arokoski, Jari P. et al. 2001. “Back and abdominal muscle function during stabilization exercises.” *Archives of Physical Medicine and Rehabilitation* 82(8): 1089-1098. http://linkinghub.elsevier.com/retrieve/pii/S0003999301859232 (Accessed July 13, 2012).

Behm, David G et al. 2005. “Relationship between hockey skating speed and selected performance measures.” *Journal of strength and conditioning research / National Strength & Conditioning Association* 19(2): 326-31. http://www.ncbi.nlm.nih.gov/pubmed/15903370 (Accessed July 12, 2012).

Bisson, E et al. 2007. “Functional balance and dual-task reaction times in older adults are improved by virtual reality and biofeedback training.” *Cyberpsychology & behavior : the impact of the Internet, multimedia and virtual reality on behavior and society* 10(1): 16-23. http://www.ncbi.nlm.nih.gov/pubmed/17305444 (Accessed April 18, 2012).

Borghuis, Jan, At L Hof, and Koen a P M Lemmink. 2008. “The importance of sensory-motor control in providing core stability: implications for measurement and training.” *Sports medicine (Auckland, N.Z.)* 38(11): 893-916. http://www.ncbi.nlm.nih.gov/pubmed/18937521.

Branca, Francesco, Haik Nikogosian, and Tim Lobstein. 2007. *The Challenge of Obesity in the Who European Region and the Strategies for Response: Summary*. http://books.google.com/books?hl=nl&lr=&id=QRLSk7M\_6nAC&pgis=1 (Accessed July 19, 2012).

Bryanton, C., Bossé, J., Brien, M., McLean, J., McCormick, A. & Sveistrup, H. (2006). Feasibility, Motivation, and Selective Motor Control: Virtual Reality Compared to Conventional Home Exercise in Children with Cerebral Palsy. *CYBERPSYCHOLOGY & BEHAVIOR Volume 9, Number 2*, 2006.

Burdea, G. (2003). Virtual Rehabilitation – Benefits and Challenges. *Methods of information in medicine.* February 2003.

Caraffa, a et al. 1996. “Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training.” *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA* 4(1): 19-21. http://www.ncbi.nlm.nih.gov/pubmed/8963746.

Cheng C.H., Chen P.J., Kuo Y.W. & Wang J.L. (2010). *Proc Inst Mech Eng H. 2011 Feb;225*(2):149-57.

Comerford, M J, and S L Mottram. 2001. “Functional stability re-training: principles and strategies for managing mechanical dysfunction.” *Manual therapy* 6(1): 3-14. http://www.ncbi.nlm.nih.gov/pubmed/11243904 (Accessed July 16, 2012).

Davids, K et al. 2000. “Effects of postural constraints on children’s catching behavior.” *Research quarterly for exercise and sport* 71(1): 69-73. http://www.ncbi.nlm.nih.gov/pubmed/10763523 (Accessed July 19, 2012).

Elbinoune I., Amine B., Shyen S., Gueddari S., Abouqal R. [&](https://www.ncbi.nlm.nih.gov/pubmed/?term=Specific+therapeutic+exercise+of+the+neck+induce) Hajjaj-Hassouni N.

(2016). Chronic neck pain and anxiety-depression: prevalence and associated risk factors. *Pan Afr Med J. 2016 May 27;*24:89. doi: 10.11604/pamj.2016.24.89.8831.

Emery, Carolyn a et al. 2005. “Effectiveness of a home-based balance-training program in reducing sports-related injuries among healthy adolescents: a cluster randomized controlled trial.” *CMAJ : Canadian Medical Association journal = journal de l’Association medicale canadienne* 172(6): 749-54.

Falla D.L., Jull G.A. [&](https://www.ncbi.nlm.nih.gov/pubmed/?term=Specific+therapeutic+exercise+of+the+neck+induce) Hodges P.W. (2004). Patients with neck pain demonstrate reduced electromyographic activity of the deep cervical flexor muscles during performance of the craniocervical flexion test. *Spine (Phila Pa 1976). 2004 Oct 1;29*(19):2108-14.

Fejer R., Kyvik K.O. [&](https://www.ncbi.nlm.nih.gov/pubmed/?term=Specific+therapeutic+exercise+of+the+neck+induce) Hartvigsen J. (2006). The prevalence of neck pain in the world population: a systematic critical review of the literature. *Eur Spine J. 2006 Jun;15*(6):834-48. Review.

Fitzgerald, D., Trakarnratanakul, N., B Smyth, B. & Caulfield, B. (2010). Effects of a Wobble Board-Based Therapeutic Exergaming System for Balance Training on Dynamic Postural Stability and Intrinsic Motivation Levels. *Journal of orthopaedic & sports physical therapy.* january 2010. volume 40. number 1.

Garrick, James G, and Ralph Requa. 2005. “Structured exercises to prevent lower limb injuries in young handball players.” *Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine* 15(5): 398.

Hazime, Fuad a et al. 2012. “Postural control under visual and proprioceptive perturbations during double and single limb stances: Insights for balance training.” *Journal of bodywork and movement therapies* 16(2): 224-9. http://www.ncbi.nlm.nih.gov/pubmed/22464121 (Accessed April 18, 2012).

Horlings, Corinne G C et al. 2008. “A weak balance: the contribution of muscle weakness to postural instability and falls.” *Nature clinical practice. Neurology* 4(9): 504-15. http://www.ncbi.nlm.nih.gov/pubmed/18711425 (Accessed April 4, 2012).

Hue, Olivier et al. 2007. “Body weight is a strong predictor of postural stability.” *Gait & posture* 26(1): 32-8. http://www.ncbi.nlm.nih.gov/pubmed/16931018 (Accessed July 19, 2012).

Hupperets, M. D W, E. a L M Verhagen, and W. V. Mechelen. 2009. “Effect of unsupervised home based proprioceptive training on recurrences of ankle sprain: randomised controlled trial.” *Bmj* 339(jul09 1): b2684-b2684.

Jansen-Kosterink, S.M., Huis In ’T Veld, R.M.H.A., Hermens, H.J. & Vollenbroek-Hutten, M.M.R. (2013). A Serious Exergame for Patients Suffering from Chronic Musculoskeletal Back and Neck Pain: A Pilot Study. *GAMES FOR HEALTH JOURNAL: Research, Development, and Clinical Applications Volume 2, Number 5*, 2013.

[Jull G](https://www.ncbi.nlm.nih.gov/pubmed/?term=Jull%20G%5BAuthor%5D&cauthor=true&cauthor_uid=17143898)., [Falla D](https://www.ncbi.nlm.nih.gov/pubmed/?term=Falla%20D%5BAuthor%5D&cauthor=true&cauthor_uid=17143898)., [Treleaven J](https://www.ncbi.nlm.nih.gov/pubmed/?term=Treleaven%20J%5BAuthor%5D&cauthor=true&cauthor_uid=17143898)., [Hodges P](https://www.ncbi.nlm.nih.gov/pubmed/?term=Hodges%20P%5BAuthor%5D&cauthor=true&cauthor_uid=17143898). [&](https://www.ncbi.nlm.nih.gov/pubmed/?term=Specific+therapeutic+exercise+of+the+neck+induce) [Vicenzino B](https://www.ncbi.nlm.nih.gov/pubmed/?term=Vicenzino%20B%5BAuthor%5D&cauthor=true&cauthor_uid=17143898). (2006) Retraining cervical joint position sense: the effect of two exercise regimes. [*J Orthop Res.*](https://www.ncbi.nlm.nih.gov/pubmed/?term=retraining+cervical+joint+position+sense+the+effect+of+two+exercise+regimes)*2007 Mar;25*(3):404-12.

[Jull G.A](https://www.ncbi.nlm.nih.gov/pubmed/?term=Jull%20GA%5BAuthor%5D&cauthor=true&cauthor_uid=19632880)., [Falla D](https://www.ncbi.nlm.nih.gov/pubmed/?term=Falla%20D%5BAuthor%5D&cauthor=true&cauthor_uid=19632880)., [Vicenzino B](https://www.ncbi.nlm.nih.gov/pubmed/?term=Vicenzino%20B%5BAuthor%5D&cauthor=true&cauthor_uid=19632880). [&](https://www.ncbi.nlm.nih.gov/pubmed/?term=Specific+therapeutic+exercise+of+the+neck+induce) [Hodges P.W](https://www.ncbi.nlm.nih.gov/pubmed/?term=Hodges%20PW%5BAuthor%5D&cauthor=true&cauthor_uid=19632880). (2008) The effect of therapeutic exercise on activation of the deep cervical flexor muscles in people with chronic neck pain. [*Man Ther.*](https://www.ncbi.nlm.nih.gov/pubmed/?term=the+effect+of+therapeutic+exercise+on++activation+of+the+deep+cervical+flexor+muscles+in)*2009 Dec;1*4(6):696-701. doi: 10.1016/j.math.2009.05.004. Epub 2009 Jul 25.

Kent, P., Laird, R. & Haines, T. (2015). The effect of changing movement and posture using motion-sensor feedback, versus guidelines-based care, on the clinical outcomes of people with sub-acute or chronic low back pain- a multicenter, cluster-randomized, placebo-controlled, pilot trial. *BMC musculoskeletal disorders 2015 May 29*; 16: 131

Kibler, W Ben, Joel Press, and Aaron Sciascia. 2006. “The role of core stability in athletic function.” *Sports medicine (Auckland, N.Z.)* 36(3): 189-98. http://www.ncbi.nlm.nih.gov/pubmed/16526831 (Accessed July 19, 2012).

Kim, S.-J., Kim, K.-H., Lee, S.-M. & Cho, H.-Y. (2016). Effects of ankle biofeedback training on strength, balance, and gait in patients with stroke. *Journal of Physical Therapy Science v28 n9* (2016 09 01): 2596-2600.

Lamoth, Claudine J C, Simone R Caljouw, and Klaas Postema. 2011. “Active video gaming to improve balance in the elderly.” *Studies in health technology and informatics* 167: 159-64. http://www.ncbi.nlm.nih.gov/pubmed/21685660 (Accessed July 12, 2012).

[Lee K.W](https://www.ncbi.nlm.nih.gov/pubmed/?term=Lee%20KW%5BAuthor%5D&cauthor=true&cauthor_uid=26957752). [&](https://www.ncbi.nlm.nih.gov/pubmed/?term=Specific+therapeutic+exercise+of+the+neck+induce) [Kim W.H](https://www.ncbi.nlm.nih.gov/pubmed/?term=Kim%20WH%5BAuthor%5D&cauthor=true&cauthor_uid=26957752). (2016). Effect of thoracic manipulation and deep craniocervical flexor training on pain, mobility, strength, and disability of the neck of patients with chronic nonspecific neck pain: a randomized clinical trial. [*J Phys Ther Sci.*](https://www.ncbi.nlm.nih.gov/pubmed/?term=Effect+of+thoracic+manipulation+and+deep+cranio)*2016 Jan;2*8(1):175-80. doi: 10.1589/jpts.28.175. Epub 2016 Jan 30.

Liaw, Mei-Yun et al. 2009. “Comparison of the static and dynamic balance performance in young, middle-aged, and elderly healthy people.” *Chang Gung medical journal* 32(3): 297-304. http://www.ncbi.nlm.nih.gov/pubmed/19527609.

Marini, Mirca et al. 2008. “Pain syndromes in competitive elite level female artistic gymnasts. Role of specific preventive-compensative activity.” *Italian journal of anatomy and embryology = Archivio italiano di anatomia ed embriologia* 113(Jan-Mar;113 (1)): 47-54. http://www.ncbi.nlm.nih.gov/pubmed/18491454 (Accessed July 12, 2012).

Nederhand, M.J., IJzerman, M.J., Hermens, H.J., Baten, C.T.M. & Zilvold, G. (2000). Cervical muscle dysfunction in chronic whiplash associated disorder grade ii (wad ii). *The Netherlands Spine 2000; 25*: 1938-1943 Reprinted with permission of Spine Cervical muscle dysfunction in WAD grade II 11

Ogaya, Shinya et al. 2011. “Effects of balance training using wobble boards in the elderly.” *The Journal of Strength & Conditioning Research* 25(9): 2616-2622. http://www.ncbi.nlm.nih.gov/pubmed/21869636.

[O'Leary S](https://www.ncbi.nlm.nih.gov/pubmed/?term=O%27Leary%20S%5BAuthor%5D&cauthor=true&cauthor_uid=17644487)., [Falla D](https://www.ncbi.nlm.nih.gov/pubmed/?term=Falla%20D%5BAuthor%5D&cauthor=true&cauthor_uid=17644487)., [Hodges P.W](https://www.ncbi.nlm.nih.gov/pubmed/?term=Hodges%20PW%5BAuthor%5D&cauthor=true&cauthor_uid=17644487)., [Jull G](https://www.ncbi.nlm.nih.gov/pubmed/?term=Jull%20G%5BAuthor%5D&cauthor=true&cauthor_uid=17644487). [&](https://www.ncbi.nlm.nih.gov/pubmed/?term=Specific+therapeutic+exercise+of+the+neck+induce) [Vicenzino B](https://www.ncbi.nlm.nih.gov/pubmed/?term=Vicenzino%20B%5BAuthor%5D&cauthor=true&cauthor_uid=17644487). (2006). Specific therapeutic exercise of the neck induces immediate local hypoalgesia. [*J Pain.*](https://www.ncbi.nlm.nih.gov/pubmed/?term=Specific+therapeutic+exercise+of+the+neck+induce) *2007 Nov;8*(11):832-9. Epub 2007 Jul 19.

[O'Leary S](https://www.ncbi.nlm.nih.gov/pubmed/?term=O%27Leary%20S%5BAuthor%5D&cauthor=true&cauthor_uid=19411767)., [Falla D](https://www.ncbi.nlm.nih.gov/pubmed/?term=Falla%20D%5BAuthor%5D&cauthor=true&cauthor_uid=19411767)., [Elliott J.M](https://www.ncbi.nlm.nih.gov/pubmed/?term=Elliott%20JM%5BAuthor%5D&cauthor=true&cauthor_uid=19411767). [&](https://www.ncbi.nlm.nih.gov/pubmed/?term=Specific+therapeutic+exercise+of+the+neck+induce) [Jull G](https://www.ncbi.nlm.nih.gov/pubmed/?term=Jull%20G%5BAuthor%5D&cauthor=true&cauthor_uid=19411767). (2009) muscle dysfunction in cervical spine pain: implications for assessment and management. *J Orthop Sports Phys Ther. 2009 May;39*(5):324-33. doi: 10.2519/jospt.2009.2872.

Onigbinde, Ayodele Teslim, Taofeek Awotidebe, and Henry Awosika. 2009. “Effect of 6 weeks wobble board exercises on static and dynamic balance of stroke survivors.” *Technology and health care : official journal of the European Society for Engineering and Medicine* 17(5-6): 387-92. http://www.ncbi.nlm.nih.gov/pubmed/20051618 (Accessed June 27, 2012).

Paulus I. [&](https://www.ncbi.nlm.nih.gov/pubmed/?term=Specific+therapeutic+exercise+of+the+neck+induce) Brumagne S. (2008). Altered interpretation of neck proprioceptive signals in persons with subclinical recurrent neck pain. *J Rehabil Med. 2008 Jun;*40(6):426-32. doi: 10.2340/16501977-0189.

Prosperini, Luca et al. 2010. “Visuo-proprioceptive training reduces risk of falls in patients with multiple sclerosis.” *Multiple sclerosis (Houndmills, Basingstoke, England)* 16(4): 491-9. http://www.ncbi.nlm.nih.gov/pubmed/20150396 (Accessed June 20, 2012).

Rose, Jessica et al. 2002. “Postural balance in children with cerebral palsy.” *Developmental medicine and child neurology* 44(1): 58-63.

Rougier, P. 2005. “Compatibility of postural behavior induced by two aspects of visual feedback: time delay and scale display.” *Experimental brain research. Experimentelle Hirnforschung. Expérimentation cérébrale* 165(2): 193-202.

Savelsbergh, Geert J P et al. 2005. “Perceptual-motor organization of children’s catching behaviour under different postural constraints.” *Neuroscience letters* 373(2): 153-8. http://www.ncbi.nlm.nih.gov/pubmed/15567572 (Accessed July 19, 2012).

Schönauer, C., Pintaric, T., Kaufmann, H., Jansen – Kosterink, S. & Vollenbroek-Hutten, M. (2011) Chronic Pain Rehabilitation with a Serious Game using Multimodal Input. *Rehab Week Zurich, ETH Zurich Science City, Switzerland, June 27* - 29, 2011.

Sihvonen, Sanna et al. 2004-1. “Fall incidence in frail older women after individualized visual feedback-based balance training.” *Gerontology* 50(6): 411-6. http://www.ncbi.nlm.nih.gov/pubmed/15477703 (Accessed June 19, 2012).

Sihvonen, Sanna E, Sarianna Sipilä, and Pertti a Era. 2004-2. “Changes in postural balance in frail elderly women during a 4-week visual feedback training: a randomized controlled trial.” *Gerontology* 50(2): 87-95. http://www.ncbi.nlm.nih.gov/pubmed/14963375 (Accessed April 25, 2012).

Sparkes, Ryan, and David G Behm. 2010. “Training adaptations associated with an 8-week instability resistance training program with recreationally active individuals.” *Journal of strength and conditioning research / National Strength & Conditioning Association* 24(7): 1931-1941. http://www.ncbi.nlm.nih.gov/pubmed/20555274.

Sturnieks, D L, R St George, and S R Lord. 2008. “Balance disorders in the elderly.” *Neurophysiologie clinique = Clinical neurophysiology* 38(6): 467-78. http://www.ncbi.nlm.nih.gov/pubmed/19026966 (Accessed March 26, 2012).

Taube, Wolfgang, Christian Leukel, and Albert Gollhofer. 2008. “Influence of enhanced visual feedback on postural control and spinal reflex modulation during stance.” *Experimental brain research.* 188(3): 353-61. http://www.ncbi.nlm.nih.gov/pubmed/18421451 (Accessed June 25, 2012).

Waddington, Gordon S, and Roger D Adams. 2004. “The effect of a 5-week wobble-board exercise intervention on ability to discriminate different degrees of ankle inversion, barefoot and wearing shoes: a study in healthy elderly.” *Journal of the American Geriatrics Society* 52(4): 573-6. http://www.ncbi.nlm.nih.gov/pubmed/15066073.

Wagner, Matthias Oliver et al. 2011. “The impact of obesity on developmental coordination disorder in adolescence.” *Research in developmental disabilities* 32(5): 1970-6. http://www.ncbi.nlm.nih.gov/pubmed/21596520 (Accessed July 19, 2012).

Watanabe, S et al. 2008. “Influence of trunk muscle co-contraction on spinal curvature during sitting reclining against the backrest of a chair.” *Electromyography and clinical neurophysiology* 48(8): 359-65. http://www.ncbi.nlm.nih.gov/pubmed/19097476 (Accessed July 16, 2012).

van der Wees, Philip J et al. 2006. “Effectiveness of exercise therapy and manual mobilisation in ankle sprain and functional instability: a systematic review.” *The Australian journal of physiotherapy* 52(1): 27-37. http://www.ncbi.nlm.nih.gov/pubmed/16515420 (Accessed July 12, 2012).

Wester, J U et al. 1996. “Wobble board training after partial sprains of the lateral ligaments of the ankle: a prospective randomized study.” *The Journal of orthopaedic and sports physical therapy* 23(5): 332-6. http://www.ncbi.nlm.nih.gov/pubmed/8728532.

Yang, D.J. ( 2016). Influence of biofeedback weight bearing training in sit to stand to sit and the limits of stability on stroke patient*. J. Phys. Ther. Sci*. 28: 3011–3014, 201

Ylinen, J., Takala, E. P.,m Nykanen, M., Hakkinen, A., Malkia, E., Pohjolainen, T.,Karppi, S.L., Kautianen, H. & Airaksinen, O.(2003). Active Neck Muscle Training in the Treatment of Chronic Neck Pain in Women: A randomized controlled trial. *JAMA. 2003 May 21*;289(19):2509-16.

Zazulak, Bohdanna T et al. 2007. “Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study.” *The American journal of sports medicine* 35(7): 1123-30. http://www.ncbi.nlm.nih.gov/pubmed/17468378 (Accessed July 13, 2012).