Evaluation of a four month rehabilitation program for stroke patients with balance problems and binocular visual dysfunction

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Evaluation of a four month rehabilitation program for stroke patients with balance problems and binocular visual dysfunction

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Abstract

BACKGROUND: Balance problems and binocular visual dysfunction (BVD) are common problems after stroke, however evidence of an effective rehabilitation method are limited.

OBJECTIVE: To evaluate the effect of a four-month rehabilitation program for individuals with balance problems and BVD after a stroke.

METHODS: About 40 sessions of 1.5 hours duration over four months with visual therapy and balance rehabilitation, was provided to all 29 participants, aged 18-67 years, in groups of 7-8 individuals. Several measures for BVD, balance, gait, Health Related Quality Of Life (HRQoL) and functional recovery were used at baseline, at the end of training and at a six-month follow up (FU).

RESULTS: We found significant improvements in stereopsis, vergence, saccadic movements, burden of binocular visual symptoms, balance and gait speed, fatigue, HRQoL and functional recovery. Moreover, 60\% of the participants were in employment at the six-month FU, compared to only 23\% before training. All improvements were sustained at the six-month FU.

CONCLUSIONS: Although a control group is lacking, the evidence suggests that the positive improvement is a result of the combined visual and balance training. The combination of balance and visual training appears to facilitate changes at a multimodal level affecting several functions important in daily life.

Keywords: Stroke, balance, visual dysfunction

List of abbreviations

<table>
<thead>
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<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>BVD</td>
<td>Binocular Visual Dysfunction</td>
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<tr>
<td>PRVD/PRVN</td>
<td>Positive Relative Vergence Distance/Near</td>
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<td>NRVD/Near</td>
<td>Negative Relative Vergence Distance/Near</td>
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<td>SAN</td>
<td>Stereo Acuity at Near</td>
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<td>BFD/BN</td>
<td>Binocular Fusion Distance/Near</td>
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<td>K-D</td>
<td>King Devick</td>
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<td>NPC</td>
<td>Near Point Convergence</td>
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<td>BESTest</td>
<td>Balance Evaluation</td>
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<td>10MWT</td>
<td>Ten Meter Walking Test</td>
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<td>MFIS</td>
<td>Modified Fatigue Impact Scale</td>
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<td>VHSQ</td>
<td>Vertical Heterophoria Scale Questionnaire</td>
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<tr>
<td>HRQoL</td>
<td>Health-Related Quality of Life</td>
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<td>GOSE</td>
<td>Glasgow Outcome Scale Extended</td>
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1. Background

Stroke is the second leading cause of death after ischemic heart disease and, among survivors, is a major cause of disability worldwide (Donnan, Fisher, Macleod, & Davis, 2008; Wittenhauser, 2012). The incidence of stroke events in Europe is predicted to rise from 1.1 million in 2000 to 1.5 million per year by 2025, largely due to the ageing population (Truelsen et al., 2006).

Disability problems are compound, and have severe consequences for the patients and their families. One common and significant problem after stroke is impaired balance. Adequate balance is fundamental for maintaining standing position and for remaining stable when changing positions, in order to perform activities of daily living, and for mobility. Balance control involves a complex incorporation of various systems, and contributing factors such as motor, sensory and cognitive impairments can interact in multiple ways (Schumway-Cook & Woollacott, 2011). Oculomotor dysfunctions may emerge together with balance problems including oculomotor functions in the versional, convergence, and accommodative systems. Resulting symptoms can be: diplopia, blur, difficulty following targets, oculomotor-based reading problems and asthenopia (Ciuffreda et al., 2007).

For some stroke survivors, it is discordances between the vestibular, oculomotor and somatosensory systems that are the dominant cause of balance problems. This disturbance involves the inability to select reliable sensory information (visual, vestibular and somatosensory systems) in order to produce the proper motor action necessary to maintain postural stability (Shumway-Cook, Anson, & Haller, 1988). Both balance problems and oculomotor problems may negatively affect any overall rehabilitative process (e.g., cognitive therapy), thus impacting adversely on an individual’s quality of life (Bachelor, Mackintosh, Said, & Hill, 2012; Jones & Shinton, 2006; Khan, Leung, & Jay, 2008).

Basford et al. (Basford et al., 2003) found that patients after traumatic brain injury (TBI) had increased reliance on visual input and tended to sway more than control subjects. However, using visual input as a compensating strategy, while having oculomotor problems, may leave the patient with severe instability and difficulties in daily living. Geurts et al (Geurts, Ribbers, Knoop, & van Limbeek) found that brain injury patients do not use their vestibular systems to resolve conflicts between the inputs from their visual and somatosensory systems as effectively as do people who have not had a brain injury. These issues taken together highlight the complexity of the symptoms and situation for patients with balance and oculomotor problems.

We have found no studies hitherto focussing upon stroke survivors with balance problems and BVD. A few studies have examined oculomotor rehabilitation within TBI populations (Thiagarajan & Ciuffreda, 2014; Thiagarajan, Ciuffreda, Capo-Aponte, Ludlam, & Kapoor, 2014) and others have studied balance rehabilitation in both stroke and TBI rehabilitation (Pollock et al., 2014), but none have addressed both issues simultaneously. In our clinic, we regularly see subjects with balance and BVD after stroke which causes them severe problems in their activities of daily living and potential to return to work.

Therefore, the purpose of this study has been firstly, to investigate whether or not individuals with balance and BVD after stroke have a better outcome in balance, binocular vision, fatigue and quality of life after an intensive rehabilitation training program performed by physiotherapists and optometrists, and secondly to examine the association with BVD and balance problems.

2. Method

This is a pilot study investigating the change from pre- to post-intervention in a group of 29 stroke subjects.

Inclusion criteria: Subjects who suffered their stroke in the prior 3 to 36 months. All subjects had both balance and binocular visual dysfunction (BVD) and were between 18 and 67 years of age.

Exclusion criteria: Pre-stroke history of BVD and balance problems, dominant hemianopsia, progressive and/or severe eye disease, progressive brain damage, any severe cognitive problems that would prevent participation in group training, and any psychiatric diagnosis or drug abuse.

Participants were recruited from 22 different municipalities in Denmark and three regional hospitals.

A total of 32 subjects were referred to the study. Two did not meet the inclusion criteria. (They were not motivated to participate in all training sessions). The remaining 30 accepted to participate and signed an informed consent statement. After termination of the programme, however, one participant was
hospitalized with severe mental illness and was excluded from data analysis.

2.1. Rehabilitation program

The participants received intensive training in groups of six or seven over a four-month period by an optometrist and physiotherapists specialized in BVD and balance problems. During the first two months they received training three times per week, and in the following two months they received training twice per week. They were instructed to do home exercises on every day in which they did not participate in group training. The home exercises changed gradually according to their individual level. Videos of the individual exercises were recorded and placed on computer tablets, which were provided to the participants to take home to support correct performance.

At all training sessions there were two physiotherapists present. Every second week the optometrist examined all participants and instructed on new oculomotor exercises. The participants had both group exercises and individual exercises.

Balance training involved individualized sensory integration, vestibular and proprioceptive exercises. Visual therapy included training of binocularity, fixation, tracking, vergence, eye-hand coordination and binocularity. The program begins by building fundamental visual abilities such as fixation, tracking, visual attention, accommodation, and binocularity early on. It continues to elaborate those skills and in the end works to embed those new skills and abilities so that the person will apply what has been acquired to real life situations. During this period with intensive visual and balance training, this program was the only rehabilitation the participants received. When the program ended they typically received work rehabilitation training.

2.2. Outcome measures

Baseline clinical characteristics: At baseline (BL) we recorded gender, age, type of stroke, location of the lesion, time since injury (TSI).

Work status: Work status was categorized as: Retired, on sick leave, in job <15 hours per week, in job ≥ 15 hours per week, and job on ordinary terms (i.e., as before injury). These categorizations were made just prior to training and at six-month follow-up.

2.2.1. Balance and gait

Balance was assessed by the Balance Evaluation Systems Test (BESTest) (Horak, Wrisley, & Frank, 2009). The BESTest is based on a conceptual model of balance control and investigates six systems of postural control: Biomechanical, Stability Limits, Postural Responses, Anticipatory Postural Adjustments, Sensory Orientation, and Dynamic Balance during Gait. Each system involves 5–7 tasks, scored on a rating scale from 0 to 3 (there are a 36 task in total). The total maximum score is 108 points, this being the sum of all of the individual items. The raw scores are converted into percentages; higher scores indicate better balance performance.

Gait performance was assessed by the Ten-Meter Walk Test (10MWT) (Flansbjer, Holmback, Downham, Patten, & Lexell, 2005). We studied gait speed at comfortable and safe fast walking speed, using a standard approach to assess gait performance. Speed is reported in metres/second.

2.2.2. Objective binocular visual dysfunction measures

Stereo acuity At Near (SAN) was assessed using the Randot Stereotest (Stereo Optical Co, Chicago, IL) (“Paul Harris Randot Test (Special Edition),”) with subjects wearing Polaroid spectacles. The test stereogram was held at a distance of 40 cm from the subject during testing. Participants with refractive errors wore their spectacles under the Polaroid lenses. Participants were asked to determine which circle in each successive group appeared to “pop out of the page”. This procedure was repeated until two mistakes were made successively. Threshold stereoacuity level was recorded in seconds of arc.

Saccadic eye movements for reading were measured using the King-Devick Saccadic Test (K-D). Subjects reads aloud a series of randomized single numbers, presented as eight rows of numbers which were read from left to right and then from the top downward, as quickly as possible. The first paragraph has the lines widely separated vertically with lines connecting the numbers on each horizontal line. The second paragraph has the same relative spacing as the first but with no connecting horizontal lines. The third paragraph has the eight rows of numbers stacked closely together. Grading for the K-D is based on the time taken to read the 40 numbers aloud on each card and finally all the times are added together.

Near Point of Convergence (NPC) was assessed using a Wolff wand placed along the subject’s visual midline. Then the wand was slowly moved towards
the bridge of the nose. Break of NPC was recorded either when the subject reported diplopia or the examiner observed one eye turning away from the wand. Then the wand was moved away from the bridge of the nose, and the subject was asked when she/he saw the two wands go back together into one, i.e. achieved fusional recovery (Recovery) (Ciuffreda & Ludlam, 2011). Positive and negative relative vergence were measured both at distance = 6 meters (PRVD and NRVD) and close up = 40 cm (PRVN and NRVN) following a standard procedure by using base-out and base-in prisms, respectively (Grosvenor, 2006).

Binocular fusion was tested using the Keystone Telebinocular using the Keystone Visual Skills test cards at both distance (BFD) (the DB-4K) and near-point distance (BFN) (DB-5K) and recorded ability to reach binocular fusion coded as yes or no (Keystone).

2.2.3. Subjective measures

Quality of life was assessed using the EuroQol 5 dimension 3 level measure (EQ-5D-3-L) (Group, 1990). This is a generic health-related quality of life questionnaire that consists of two parts. Part one covers health status in five dimensions: mobility, personal care, daily activities, pain/discomfort and anxiety/depression. The five scale scores are pooled into a global index ranging from 0 (worst state of health possible) to 1 (perfect state of health). The global index has been validated in a Danish translation (Sorensen, Davidsen, Gudex, Pedersen, & Bronnum-Hansen, 2009; Wittrup-Jensen, Lauridsen, Gudex, & Pedersen, 2009). Part two is a 200 mm Visual Analog Scale (VAS) rating state of health, between 0 (worst possible) and 100 (best possible).

We measured functional recovery using the Glasgow functional Outcome Scale – Extended (GOSE), which classifies functional outcome in eight levels: Minimum Score = 1 equals death; score 2 corresponds to vegetative state; score 3–4 = severe disability; score 5–6 indicate moderate disability, independent and score 7–8 correspond to good recovery (Wilson, Pettigrew, & Teasdale, 1998).

The binocular visual symptom burden was assessed by the Vertical Heterophoria Symptom Questionnaire (VHS-Q) which is a self-administrative survey used to assess improvement of symptoms for vertical heterophoria (VH) (Doble, Feinberg, Rosner, & Rosner, 2010). It comprises 25 items, each with a score 0–3. The higher the score, the more severe problems. In a recent study, we extracted four meaningful factors using a principle component analysis, followed by varimax rotation 1) Dizziness, 2) Reading problems, 3) Pain/sensory, 4) Binocular problems (*submitted for publication).

Fatigue was measured using Modified Fatigue Impact Scale (MFIS) recently validated in a brain injury population (Schiehser et al., 2015). Participants rated how often fatigue has affected 21 functions during the preceding four weeks, using a 0 (never) to 4-point (almost always) 5 point Likert scale. The summed total thus ranges from 0 to 84, with higher values indicating greater impact on fatigue. In a recent study, we found that the items can be aggregated into a total score (21 items) as well as four subscales: 1) Cognitive fatigue, 2) Physical fatigue, 3) Arousal, 4) Physical uncomfortable (*submitted for publication).

Subjects were tested with the total test battery before starting treatment, at the end of the four months of treatment and three and six month post-treatment follow-up visits.

The project has been approved by the Danish Data Protection Agency j.nr. 2014-41-3324. All participants provided informed consent.

3. Statistics

The mean and standard deviation (SD) were used as descriptive statistics. Kolmogorov–Smirnov tests were used to investigate the normality of distribution of the studied variables. General linear repeated measures ANCOVA was used to determine the change in normally distributed variables across time and the Wilcoxon test was used for non-normal distributed variables using SAS for windows Version 9.3.

Pairwise correlation between subjective and objective visual measures and balance and gait were analyzed and visually presented using heatmap, conducted in Matlab® R2014b using the PLStoolbox (ver 7.9.5 - Eigenvector Inc ©), the statistical toolbox v 8.1.

4. Results

All 30 participants completed the training period. One participant suffered from a severe depression during the study and was hospitalized. All data from this participant was excluded (N = 29).

At the three-month follow up visit, one participant had a fall injury which markedly affected walk and balance performance; we therefore excluded the
participant’s data from further analysis. Additionally, one participant had a recurrent stroke prior to the three-month follow-up and two more participants had strokes between the three month and six-month follow-ups. Such the follow-up data include at three-month ($N=27$) and six-month follow-up ($N=25$), respectively.

Demographic data are presented in Table 1.

At the six-month follow up visit, 60% of the participants were in some form of employment compared to 24% at BL and 27.6% were in ordinary full-time employment at FU, compared to only 3.3% at BL.

### 4.1. Balance and gait

The improvement and variation in BESTest total score and the subcategories from baseline (BL) to six-month FU are presented in Fig. 1; all changes are statistical significant ($p<0.001$). As expected, we found the lowest score at BL sub-category “instability in gait” and secondly “sensory integration”. The greatest increase was also seen in “stability in gait”.

Gait velocity increased from BL until after a three-month training period for fast gait speed and then stabilized during the follow up period and the comfortable walking speed increased during all four months of training and stabilized during the follow up period. The increase in comfortable and fast speed from BL to the six-month FU visit was significant ($p<0.001$) and almost equal, 0.20 m/s and 0.19 m/s respectively. There was very little difference in both comfortable and fast walking speed between men and woman. At BL, men had a comfortable speed of 0.99 metres/second (SD: 0.21) and fast speed of 1.29 (SD: 0.30) whereas women had a comfortable speed of 0.95 metres/second (SD: 0.17) and fast speed of 1.16 (SD: 0.18) and at the six-month FU visit men had a comfortable speed of 1.16 (SD: 0.24) and fast speed 1.43 (SD: 0.34) and women had a comfortable speed of 1.20 (SD: 0.23) and fast speed of 1.43 (SD: 0.37).

### 4.2. Visual disorders

All measures: SAN, K-D, BFN, PRVN and PRVD improved significantly from BL to the 6-month FU
### Table 2

<table>
<thead>
<tr>
<th></th>
<th>Baseline Mean (SD)</th>
<th>End training Mean (SD)</th>
<th>6 month follow up Mean (SD)</th>
<th>Change from BL to 6 month FU p (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stereopsis (sec.arc)</td>
<td>269.20 (259.50)</td>
<td>128.00 (186.68)</td>
<td>98.18 (140.29)</td>
<td>0.0017</td>
</tr>
<tr>
<td>K-D (time (sec))</td>
<td>92.45 (34.58)</td>
<td>65.89 (31.78)</td>
<td>61.96 (23.23)</td>
<td>&lt;0.001 (&lt;–34.47 – –17.00)</td>
</tr>
<tr>
<td>NPC (break)</td>
<td>9.12 (8.36)</td>
<td>5.57 (5.04)</td>
<td>4.94 (5.24)</td>
<td>&lt;0.001 (&lt;–6.83 – –2.41)</td>
</tr>
<tr>
<td>Binocular fusion (%)</td>
<td>93.10%</td>
<td>44.80%</td>
<td>32.00%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PRVN_{break}</td>
<td>15.91 (6.99)</td>
<td>18.40 (6.58)</td>
<td>18.78 (6.96)</td>
<td>0.03 (0.33 – 5.80)</td>
</tr>
<tr>
<td>PRVD_{break}</td>
<td>12.09 (4.56)</td>
<td>15.88 (7.25)</td>
<td>16.45 (7.73)</td>
<td>0.03 (0.31 – 6.41)</td>
</tr>
<tr>
<td>NRVN_{break}</td>
<td>21.56 (4.73)</td>
<td>21.19 (5.53)</td>
<td>20.39 (4.72)</td>
<td>0.58 (–2.33 – 1.34)</td>
</tr>
<tr>
<td>NRVD_{break}</td>
<td>8.96 (3.31)</td>
<td>8.28 (2.94)</td>
<td>8.60 (4.44)</td>
<td>0.46 (–0.58 – 1.23)</td>
</tr>
</tbody>
</table>

Changes in MFIS total, MFIS cognitive, MFIS physical and our four new MFIS components are presented in Fig. 3. All numbers and figures are expressed as percentages, and not raw scores, to facilitate comparisons. Participants score relatively lower on the cognitive component compared to the other components. The decrease in MFIS cognitive fatigue continued after the four-month training period, whereas for the MFIS physical components, and MFIS arousal (new) and MFIS discomf. (new), the level stabilized until the three-month FU visit and then a slight decrease occurred to the six-month FU visit. The results for change in MFIS total and the cognitive and physical and the four new components were: MFIS total 24.71% (SD: 20.40), MFIS-physical 27.50% (SD: 24.76), MFIS-cognitive 22.18%, (SD: 20.08), MFIS-physical (new) 33.8% (SD: 24.7), MFIS cognitive(new) 31.03 % (SD: 26.70), MFIS arousal(new) 30.75% (SD: 26.99) and MFIS physical discomfort.

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**4.3. Subjective outcome**

Subjective BVD measured by VHS-Q change 17.64 (SD: 14.55) from BL to the six-month FU visit. The four extracted components, dizziness, reading problems, pain/sensory and visual problems are presented in Fig. 3 showing changes in dizziness 28.45 (SD: 22.35), reading problems 30.03 (SD: 29.94), pain/sensory 11.90 (SD: 22.58) and visual problems 26.72 (SD: 30.04). Problems in VHSQ-reading and VHSQ-dizziness were the two components where participants showed the highest level of disabilities, followed by visual problems and pain. The change in score followed the level of problems, the greatest problems showing the greatest difference. All changes were statistically significant \((p < 0.01)\) (Fig. 2).

![Fig. 2. Change in VHSQ-total score and 4 domains, from baseline, mid-training, end training and at 3-and 6 month follow-up.](image-url)
(new) 35.34% (SD: 44.08); (p < 0.01 for all MFIS components).

Functional recovery as measured by GOSE, showed that at BL 44.4% had severe disability (GOSE = 3-4), 55.2% had moderate disability (GOSE = 5-6) and only one person 3.4% had good recovery (GOSE = 7-8). At the end of training 20.7% still suffered from severe disability, 62% moderate disability and 17.2% showed good recovery. At the 6 month FU visit only 8% continue to have severe disability, 68% moderate and 24% had good recovery. The change in the GOSE mean is statistically significant (P < 0.01).

HRQoL (see Fig. 4): The overall mean EQ-5D-3L index score was at BL: 0.643 (SD: 0.14) and at the 6 month FU: 0.743 (0.199), representing a statistically significant change of 0.1 (p = 0.01). The visual analogue score were at BL: 46.03 (SD: 19.72) and at 6 month FU 62.36 (SD: 22.11), change 14.56 (p < 0.001), respectively. Fig. 5 shows the EQ-5D-3L scoring in the different domains. The lowest level of reported problems was in Self-care where 82.8% reported no problems at BL and 88% at the 6 month FU. The highest level of problems was reported in usual activities where no one reported no problems at BL whereas 24% did so at the 6 month FU.

The association analysis between BVD measures and balance/gait are presented in the heat map – see Fig. 5.

There were a number of significant results follows.

Gait speed fast was associated with: K-D, PRVN, VHSQ-reading, VHSQ-pain and VHSQ-vision.
BESTest-Stab gait was associated with: PRVD, NRVD, all the VHSQ components.
BESTest-sensory orientation was associated with: VHSQ-dizziness, VHSQ-vision, PRVN, NRVD and SAN.
BESTest-reactive postural control was associated with PRVD, VHSQ-reading and K-D.
BESTest-stability limits was associated with SAN.
BESTest-postural adjustment was associated with VHSQ-dizziness, VHSQ-vision, PRVN, NRVD and SAN.

5. Discussion

The present study shows that individuals with balance impairments and BVD after stroke achieved a significant improvement in balance, gait and most BVD measures during a four-month rehabilitation period. They also reached a lower level of fatigue and higher level of HRQoL. This recovery was sustained over time to their six-month FU. Almost all the measured functions had the same course, with an improvement from start of training until end training and then a plateau until follow-up. We consider that this change suggests an effect of the rehabilitation program, since such improvements are unlikely to have occurred spontaneously. It is recognised however, that the lack of a control group in our study means that other causes than the program itself could not be fully excluded. This is especially relevant for the results at follow-up, since subjects in this study, most often participated in a work rehabilitation program when finishing this visual and balance training. During the training period, the program in this study was the only training received. The work rehabilitation may contribute to work status at six month follow-up, facilitated by the improvements during the four month balance and visual training. Moreover, impairments of balance and gait (Wilkinson et al., 1997) and fatigue (Radman et al., 2012) have been documented to be persistent over time in stroke survivors supporting the hypothesis of the effect of our program.

5.1. Balance and gait

We used the BESTest to evaluate balance in order to distinguish which underlying systems contribute to the balance problems in the individual participants, in order to carry out the best possible training to each participant. At baseline, we found that the most severe problems, compared to normative values in a similar age group in a healthy population (O’Hoski et al., 2014), were: sensory integration, reactive postural control and stability in gait. At the end of training the group showed the biggest difference from normative values in reactive postural control and sensory integration. Since our participants all had some kind of visual problems, it seems consistent with their other symptoms that they experience problems with sensory integration that involves visual information (Horak et al., 2009). However, examining reactive postural control, the examiner uses a push and release technique in order to test the postural response. A number of our participants reported that they were nervous of falling during this test which may affect the examiner’s procedure or the participant’s performance, and thus the score on the test. Still, this domain will in our future training, be of special focus, since the correct use of postural reactions will provide stability when recovering equilibrium, an ability
Fig. 3. Change in MFIS-total, MFIS physical and MFIS Cognitive and the 4 (new) components, from baseline, mid-training, end training and 3 and 6 month follow-up.

Fig. 4. EUROquol EQ-5D-3 L.
highly relevant in daily life (Jacobs, Horak, Van Tran, & Nutt, 2006).

We found almost no difference in walking speed between men and women. Our participants had a greater disparity from a normal population in similar age range in fast walking speed, at the 6 month FU visit, (difference: men = 0.64 m/s; woman = 0.61 m/s) than in comfortable walking speed (difference: men = 0.23 m/s; woman = 0.20 m/s) (Bohannon, 1997), however, change in both fast and comfortable walking speed are clinically important (Fulk et al., 2011). The greater difference in fast walking as compared to comfortable walking speed, can be explained by the remaining balance- and visual dysfunctions. It may be easier to compensate at a comfortable speed and more difficult when hurrying. The participants in this study may additionally suffer from muscle weakness after stroke, which has been shown to affect walking speed (Bohannon, 1997). Lack of muscle strength is more significant in faster speed, therefore strength training may be beneficial to gain better performance, and could be relevant to include in future training programs. The change in gait and balance may also reflect the change in GOSE where we found a decreased of the numbers of participants with severe disability and an increase in subjects with moderate disability and in good recovery of 20%.

5.2. Visual disorders

We have been unable to find any studies reporting on visual therapy and physiotherapy performed in multidisciplinary teams, as in our rehabilitation program.

In general, participants recovered very well in the BVD measures, showing that optometric vision therapy can be very important in the rehabilitation of subjects with BVD and balance problems after stroke. Participants attained a ‘normal’ value of NPC of <5 cm (Scheiman et al., 2003) at the 6 month FU, this being the only BVD measure to reach a normal value.

NRV and BFD did not improve during the rehabilitation period. The vision therapy program appears not to have allowed an adequate time to address NRV since the focus was primarily PRV and only six participants suffered from BFD. Therefore BFN was prioritized during the rehabilitation program.

Stereoacuity on the other hand, improved very well, without reaching normal values for participants’ ages, established by Lee and Koo (2005) (Lee & Koo,
to be 37.5 seconds of arc. Our group was at 98 seconds of arc at the 6 month FU, which is an improvement of 62%. It is important to note the very substantial standard deviation at BL of 259 seconds of arc. This argues that the rehabilitation program needs to be very individualized even though participants also benefit in group exercises and training.

5.3. Subjective measures

Our result supports a multifactorial concept of fatigue. The participants showed a significant level of fatigue in all four MFIS components. For comparison purposes we used the MFIS components found by Schiehser et al. (27) in a group of TBI patients, where they also calculated cut-off values of fatigue: MFIS total = 29.00, physical = 14.5 and cognitive fatigue = 18.5. Our MFIS results at the 6 month FU showed that our participants were below the cut off for cognitive fatigue, but still have a significant level of physical fatigue. Our intervention did not involve physical training. However, the participants were instructed in ways to structure their activities throughout the day, to avoid overtraining. This may have affected the level of perceived fatigue such as the improvement in BVD and balance and gait.

To our knowledge our study is the first to have used VHSQ components to show changes over time. We found that reading problems were the most significant, with dizziness and visual problems also being at a high level at baseline. Since participants included in this study suffered from BVD and balance problems, it seems that the burden of symptoms in this group is captured very well in the VHSQ. This questionnaire may be used as a screening instrument to identify level of symptoms and the specific domain of problems, these being important when planning a rehabilitation program.

The many significant associations between balance/gait and BVD measures indicate that it can be very relevant to train these functions parallel in a multidisciplinary program. Both gait and reactive postural response involves using the correct ankle movements that has been found to be associated with an injury in the basal ganglia (McCrimmon et al., 2015). Control of vergence has also been suggested to involve the midbrain (Thiagarajan & Ciuffreda, 2013). If the same area is damaged by the stroke, this may be part of the association. Moreover, the motor neurons involved in vergence might be similar to saccades (Thiagarajan & Ciuffreda, 2013), illustrated in the association of gait and K-D and VHSQ reading.

6. Conclusion

In conclusion, we found an overall improvement in nearly all measures of binocular visual dysfunction, gait velocity, balance and subjective measures as fatigue and HRQoL, during a four-month rehabilitation program in individuals with BVD and balance problems after stroke. The level of function was thereafter substantially stable across a follow-up period. Several BVD measures were associated with gait and balance measures, supporting the concept of training these symptoms as one complex phenomenon.

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Conflict of interest

This study was carried out with financial support from the Fund for Better Working Environment and Labour Retention and the Danish Health Foundation. The authors have no conflict of interest in connection with this study.

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