UNIVERSITY OF AGDER

Sling Exercise Therapy (SET) for children with impaired motor coordination

- achieving distal control through proximal stability - a pilot study

Geir Tore Johansen

Supervisor
Stephen Seiler

This Master's Thesis is carried out as a part of the education at the University of Agder and is therefore approved as a part of this education. However, this does not imply that the University answers for the methods that are used or the conclusions that are drawn.

University of Agder, 2012
Faculty of Health- and Sport Sciences

Abstract

Purpose: This study examined the effect of an eight week Sling Exercise Therapy (SET) training programme in children and the response to their gross and fine motor coordination skills. **Methods:** The study was a non-controlled experimental design. An intervention group consisting of 13 boys aged 8 to 12 years identified with motor coordination difficulties trained in an eight week long SET programme designed to strengthen their proximal stabilizing musculature. Pre and post testing were performed using the Movement Assessment Battery for Children (M-ABC-2) and a self developed Grapho-motor Function Test for Children (GFTC) to quantify any changes in motor coordination and drawing skills. The GFTC comprised three different figures of varying complexity for retracing/drawing on a digitizing board. A specially designed computer programme calculated accuracy through to unique variables; *mean error* and *error standard deviation.* These were combined with time to give a score on precision. On the M-ABC-2 the 25th percentile were used as a cutoff for entry into the project. Qualitative observations and unsolicited feedback regarding the children's improvements were noted during the period. **Results:** Significant changes were observed on the M-ABC-2 total score after the training intervention, from 64.9 on the pre test to 74.1 on the post test ($p<0.01$). The effect was even stronger for the group below the 16th percentile; from 60.4 to 72.3. All children initially identified at or below the 5th percentile had improved out of this zone on post testing. Eight subjects improved past the 25th percentile. For the GFTC there was a strong tendency for improvement within the group, from a precision score of 62.8 on the pre test to 48.0 on the post test ($p>0.05$). For the group below the 16th percentile on the M-ABC-2 there was a marginally significant improvement on the GFTC from a precision score of 68.3 to 47.6 ($p<0.05$). Qualitative feedback included functional improvements in everyday activities. **Conclusion:** Training the proximal stabilizing musculature of children with motor coordination problems seems to yield considerable improvements in their motor control skills. Findings suggest that this may also apply to grapho-motor function. Due to limitations in this study further research is required to properly document these effects.

Acknowledgements

I would like to direct much appreciation and a big thank you to my mentor, Stephen Seiler. He took me under his wings for this project, and even though I was gone for three years learning a completely different trade, he took his time to guide me through finishing the thesis, despite a new and hectic job as Dean. His vast insight within health & sport research, his objectivity, and constructive and precise criticism, seem to come from an inexhaustible reservoir of knowledge. I am glad that I have been able to absorb some of it.

A special thanks to Anne Kristine, for the years we have spent together working on this project. It would certainly not have been the same without you. In addition to the professional contributions, your positive spirit and quirky sense of humor have brightened many of my days. Your support has been greatly appreciated.

A big thank you to my older brother, Roar, who sat aside important time to help with this project. You also offered valuable insight and advice, and can always be relied on. This may not have been possible without you.

Finally, big thanks to school management, teachers, pupils and parents at the school that participated in this project. It was a great experience to meet so many positive people and to receive so much valuable feedback.

Kristiansand, May 2012

Geir T. Johansen

Contents

1.0 Introduction

1.1 Background

Sling Exercise Therapy (SET) is a relatively newly developed training method that has demonstrated unique effects on deep stabilizing musculature, neuromuscular control and musculoskeletal complications (24,27,33,40,44). Positive clinical outcomes have been demonstrated in individuals suffering from low back pain or shoulder impingement and it is postulated that this happens through a sort of "reactivation" of “dormant” or inactive musculature - a condition that can arise from longer periods of pain and/or inactivity (25,26, 30,32,33,47). It has also been demonstrated that SET training has a positive effect on force, shooting velocity and balance in soccer, as well as throwing velocity in handball, and maximal clubhead velocity in golf (34,35,36,43). SET is based on open- and closed kinetic chain exercises, and addresses the principle of strengthening the core musculature of the body through instability training in different slings (37). The findings of improved force, velocity and balance in a number of already highly trained individuals, suggest that training core musculature through SET, as opposed to regular strength training, improves energy transfer from proximal to distal segments.

The connection between proximal stability and force transfer through distal segments also has relevance for non-athletes. A hypothesis has emerged based on the idea that “proximal stability facilitates distal control”. Individuals with reduced motor coordination came in focus, and a small, unpublished test was performed on children with writing disabilities and other motor coordination problems. Two physical therapists trained a small group of children in only one session of 45 minutes. With several of the children, acutely improved writing speed and skill, and less reliability on arm support during the writing task was observed (Sandvikmoen, unpublished observations). This small pilot project was the stimulus for a more standardized experimental approach. The goal was testing the hypothesis that improvement in core stability among children with coordinative difficulty would also lead to improved distal control, measured as both gross- and fine motor coordination.

1.2 Diagnosis and comorbidities

The most common and established diagnosis for motor coordination impairment is Developmental Coordination Disorder (DCD) (2) or *Specific developmental disorder of motor function* (45). Prevalence is normally considered at about 5% in the population (2,13,15), but it is assumed that another 10% have milder motor coordination problems (15). Diagnosis is made by a physical therapist or other qualified professional using the Movement Assessment Battery for Children 2 (M-ABC-2) (15). This test is normally performed after the child has been referred to specialists due to concerns from the parents or the teacher. It not only determines whether the child being tested has motor control problems or not, but also to what degree it is affected. A child may in fact suffer from motor control problems, but not to a large enough extent to fall within the diagnosis. It should be stressed that the results from the M-ABC-2 alone are not sufficient to establish a DCD-diagnosis, as there are other criteria that must be considered as well (2,15,45). The M-ABC-2 test simply determines the presence and degree of motor control problems. The score a child achieves on the test determines in which *percentile* the child is to be placed, which again is directly indicative of where the child is in the general population. For instance, if a child obtains a score equivalent to a percentile rank of 15, then we know that 15% of children in the general population perform at this level or lower. Cutoffs have been made at 5% and 15%. A child whose score falls at or below the 5^{th} percentile is identified as having severe motor difficulties and a score between the 6^{th} and 15^{th} percentile inclusive is considered in an "at risk" category. DCD is normally considered likely when a child scores below the 16^{th} percentile. A score above this is generally regarded as not being indicative of any significant movement difficulties (15).

Motor coordination impairment is also often associated with a comorbid disorder such as Attention Deficit and Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD), Specific Language Disorder (SLI) and/or Reading Disability deficit (RD), further complicating identification and treatment (8,12,16,20). Children with DCD have also been shown to be more prone to behavioral problems, learning disabilities, problems with self-esteem, social deficits, anxiety and health related hazards such as overweight and obesity. Hence the impact of the disorder is often significant and without intervention it is likely to follow the individual also into adulthood (3,4,5,38,41).

1.3 Disorder characteristics

Several studies show that children with motor control impairment have longer reaction times, different muscular activation patterns and also more erratic muscular activity than typical developing (TD) children (19,46). It has also been suggested that these children have deficits in visual-spatial processing, visual-kinesthetic integration and kinesthetic perception (1,41). Academically they often present problems with hand writing; spending significantly longer time to write the same number of words as TD-children, making more corrections and writing less legibly. They use more complex transitions between letters and words, and apply less pressure to the surface (figure 1) (31). Impact on grapho-motor function and manual dexterity is also significant: DCD-children display less accuracy in a movement, spend more time and have longer trajectories than that of TD-children in controlled arm movements (figure 2) (1,19,29). There are also differences with the removal of vision, forcing improved reliance of kinaesthetic feedback. DCD-children display less difference in performance between aiming tasks with and without vision, compared to TD-children. From this reason it is suggested that children with DCD may have some kind of deficit in perception or integration of visual information, or a deficit of the kinaesthetic system (1).

Miyahara el. al (2008) studied postural control in relation to drawing errors in children struggeling with inattention, hyperactivity and motor difficulties. Between two groups of children characterized either as accurate or inaccurate drawers from results on the Movement ABC, it was found that drawing errors were not related to inattention or hyperactivity, but rather postural control (23). This finding supported that of Johnston et. al (1992) where children with delayed gross motor development who received postural support improved their pegboard performance. This was not the case in TD-children (Johnston et. al. 1992, in 23).

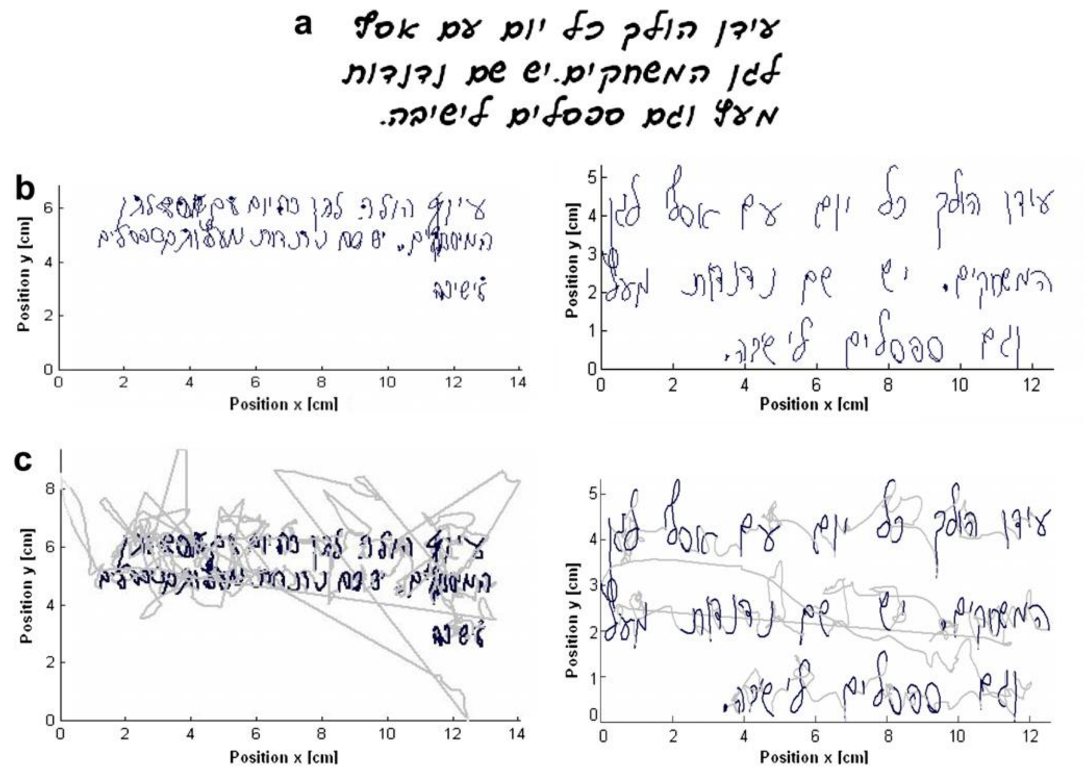


Figure 1: The figure displays the paragraph being copied (a) and writing of a TD-child (b left) and a DCD-child (b right). (C) displays in air motion for the TD-child (left) and the DCD-child (right). The letters/paragraph being copied are in Hebrew (31).

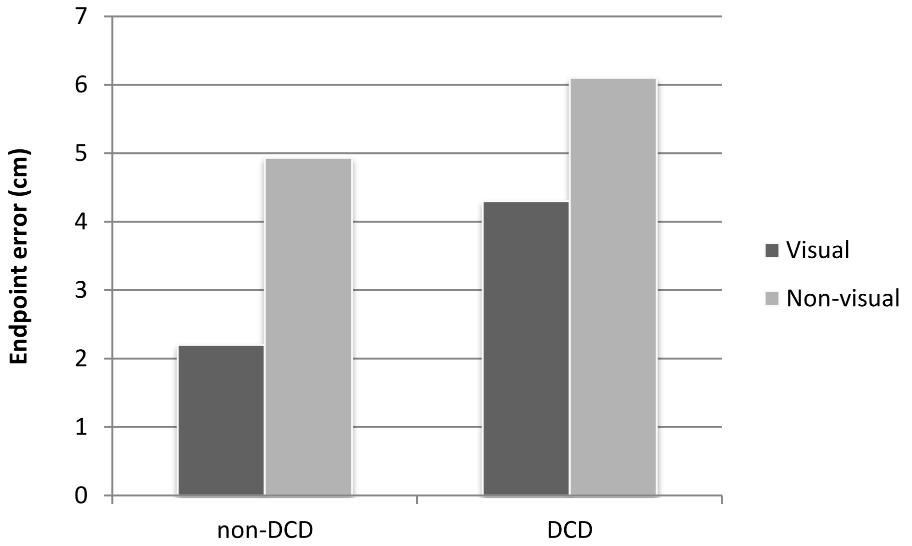


Figure 2: Differences during combinations of visual and kinesthetic (non-visual) controlled aiming exercises in children with and without DCD. Children with DCD demonstrate larger endpoint errors under all conditions, but less difference between the reliance of vision and the reliance of kinaesthesia alone (reworked from Ameratunga et. al (2004)).

In addition to manual dexterity and grapho-motor function, children with DCD often have poorer balance- and postural control (figure 3) (6,7,10,11,14,23). Tests on balance platforms have indicated a greater postural sway and movement of the centre of pressure under all testing conditions, including when no indication of balance problems were demonstrated on the M-ABC. Further, when they were blindfolded, mean sway velocity increased, whilst remaining the same in TD-children (6,7).

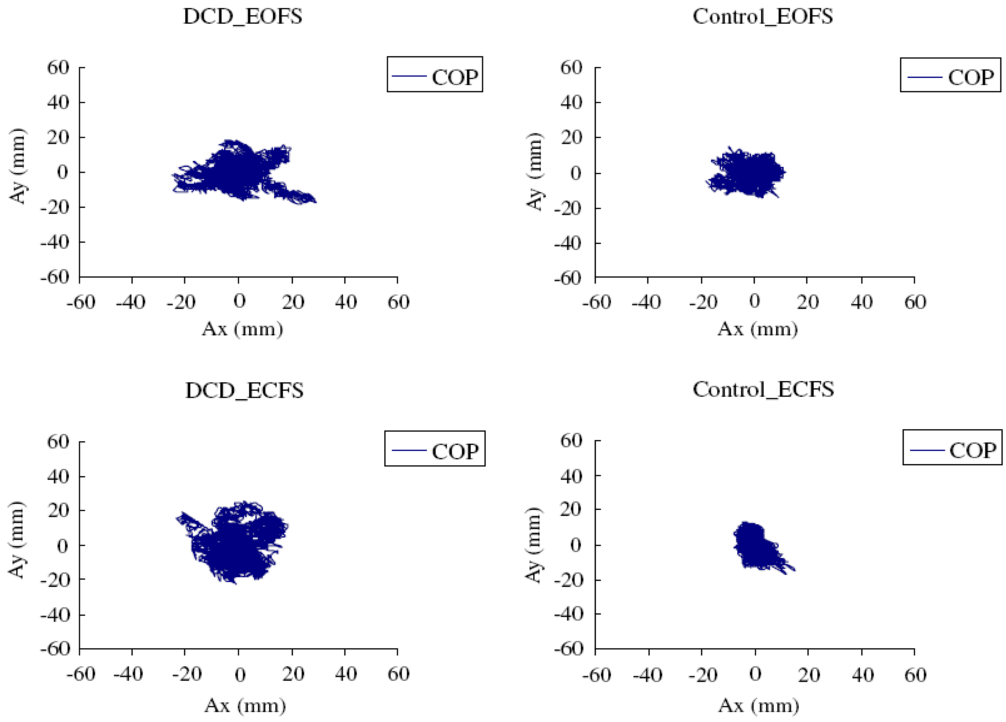


Figure 3: Illustration of sway area for the center of pressure (COP) on a platform test for children with- and without DCD. Figure shows two conditions: EOFS (eyes open, fixed foot support) and ECFS (eyes closed, fixed foot support). DCD-children show significantly larger postural sway under both conditions (6).

Reduced postural control has been associated with timing of the stabilizing musculature in several studies, especially in the preparatory phase of a movement (10,11,18,19). Whilst with TD-children activation of all stabilizing muscles in the trunk happens in advance of the primary muscles used in the movement, DCD-children display a significantly delayed activation in three out of five muscles. In the shoulder region there was a significantly earlier activation of several muscles than that of the TD-group for an arm movement (figure 4). The authors suggested that the different muscular activation patterns contributes to a lower degree of proximal stability, which in turn cause poor control of the arm movement when aiming for a specific target (19). Hence, control of the distal segments of the body is reduced as a result of an inability to properly stabilize the trunkus.

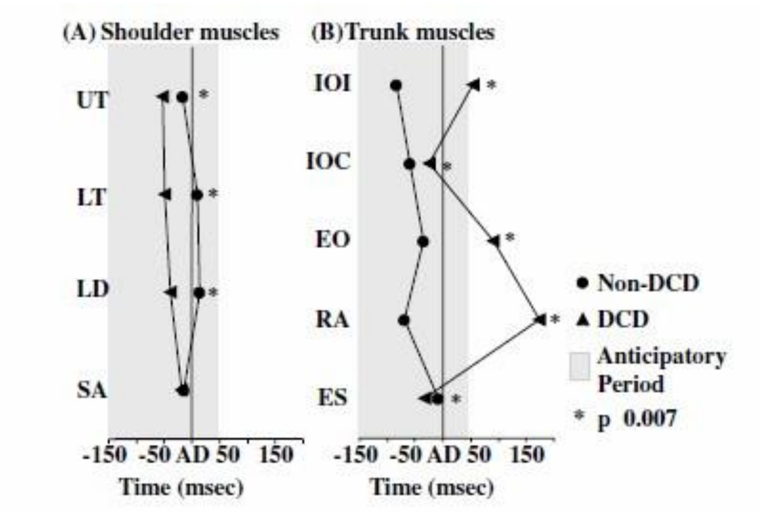


Figure 4: Mean relative latencies for muscles in the shoulder (A) and the trunk (B) in relation to the prime mover Anterior Deltoideus (AD) (19).

The basis for this research assignment is derived from some of the findings outlined above. It has been demonstrated that these children have coordination- and movement abnormalities from the deep stabilizing musculature to the very tip of their fingers; through problems with postural stability, abnormal muscular activation patterns, erratic muscular activity, and consequently writing problems and poorer precision in their movements. Our hypothesis is that specifically training the proximal, stabilizing musculature through SET will improve distal control and hence grapho-motor function for children with reduced motor competence.

1.4 Research question

Does training of proximal stabilizing musculature, through SET, improve the motor capabilities of children identified as having impaired motor coordination?

2.0 Methods

2.1 Methodological approach

The study was a non-controlled experimental design. One group of test subjects from a local elementary school completed an 8 week training intervention, with two sessions of 40 minutes each week. Pre and post testing were performed in the two weeks before and after the intervention, assessing the subjects motor coordination capabilities. Originally the study was planned with a control group from a second elementary school, but this design had to be abandoned when the second participating school decided to drop out one week before the project started. The intervention school did not have enough potential motor impaired subjects for a control group and the project could not be delayed any further because of the impending summer holiday.

2.2 Test subjects

A total of 17 subjects were recruited into the project, all children ranging from 3rd through 7th grade; aged 8 to 12 years. Third grade was chosen as a minimum entry level into the project in regards to the increasing expectation of fine grapho-motor proficiency from that age. They were all identified by their teachers as candidates, based on observations of exhibiting problems with motor coordination both during regular classes and gym classes. All subjects identified were boys.

<u>Inclusion criteria:</u>

- Test subjects between 8 and 12 years of age (3rd through 7th grade).
- Identified by their gym- and classroom teachers after a long time of observation as exhibiting problems with motor coordination.
- Exhibiting motor coordination problems on the M-ABC-2, with a test score at or below the 25th percentile.

Exclusion criteria:

- Children who were identified by their teachers as "appearantly motor deficient", but did not score at or below the 25th percentile on the M-ABC-2 during pre testing, were included in all of the testing and training, but excluded from the statistical analysis.
- Children with known disorders such as Autism Spectrum Disorder, Down's syndrome and other mental retardation were excluded from the project at the level of intitial teacher identification.

Thirteen out of the 17 test subjects scored at or below the 25th percentile on the M-ABC-2 test and were included in the statistical analysis. The remaining four that scored above this cut-off were still allowed to participate in the intervention and post-testing to avoid any concerns about discrimination among the children, but were excluded from subsequent data analysis. The 25th percentile was chosen from a design perspective, as the number of test subjects from the beginning was quite low. To have a reasonable number for a pilot study this artificial cutoff was chosen, and at or below the 25th percentile was characterized as motor coordination problems, although not within parameters for a DCD diagnosis. All 17 subjects completed the intervention and testing successfully.

Ethical considerations

Written invitations were sent out to all parents (appendix 1 and 2), briefly informing them of the project and inviting them to an informational meeting. In advance, school staff had by telephone acquired verbal consent from each pair of parents to distribute the names of project candidates to us. A written consent form was also included in the invitation (appendix 3), which the parents could send in return should they decide not to participate at the meeting, but still agree to their children's participation in the project. They were also informed both verbally and in writing that their child could be withdrawn from the project at any time. The project was approved by the Health and Sport Faculty ethical board at the University of Agder.

The testing- and training intervention were organized to have minimal impact on the children`s regular school day. Training was integrated either as a part of their PT-classes, After School Program (SFO) or extracurricular activities. They were tested individually and no attention were directed to whether their performance were "good or bad". They were continuously encouraged and received positive feedback on their efforts, but did not receive objective information regarding their results.

2.3 Development of a grapho-motor function test for children

In order to measure children's distal control in a functional manner we developed a new testing method where the test subjects could not rely on any type of support for their arms or body. Previous methods have either involved tests sitting down, through aiming tasks, drawing or hand writing (1,23,29,31), or through goal directed upper limb movements towards a specific target (19). No studies have been found combining drawing and upper limb movement during unsupported stance. The purpose of our method was to ensure a connection between upper body stabilization and distal limb control without the possibility of subjects using various support solutions, such as leaning on the table (observed in preliminary care studies). We also wished to quantify the accuracy of movement during a dynamic fine-motor task resembling writing/drawing. A complex drawing task quantifying a combination of accuracy and time spent was developed, here referred to as the Grapho-motor Function Test for Children (GFTC) (17). The test involved standing upright on the floor, completely unsupported, performing a complex drawing task on an electronic digitizing board. The board was able to register the movement of an electronic pen very precisely.

The equipment and software used for GFTC was delivered to us by The Logic Group® in Austin, Texas, and consisted of the following:

- Numonic Accugrid AF90.D 36436 inch large digitizing board.
- Cordless electronic stylus pen, rechargeable.
- Accuracy Digi© 1.0 Software, The Logic Group®.

The large digitizing board was connected to a laptop PC on which the Accuracy software was installed. The board is electromagnetic and according to the manufacturer able to register movement of the stylus pen with an accuracy of 0.025cm. Although the tip of the pen was sensitive to touching the digitizing board, there was also a small, red button on the side of the pen. When pressing it the digitizing board would not stop recording movement even if the pen left the surface of the board for a split moment. For the purpose of this study the software was customized for us by John Walsh at The Logic Group®, enabling us to measure the movement of the electronic stylus pen relative to a preloaded target drawing pattern very precisely. Reliability and accuracy have been tested and demonstrated (17).

The basic function of the digitizing board and software is to compare a pre-loaded figure to a redrawing/retracing of the same figure. Three figures were permanently sketched on the board and stored in the software by the use of solid, card-board models. The program would then calculate the precision of a tracing of these figures performed with the stylus pen. Output would be *mean error* and *error standard deviaton.* The mean error indicates the average absolute deviation from the original line/figure, whilst the standard deviation quantifies the degree of variation in the retrace accuracy. Both measurments are given in millimeters and related to the error distance from each parallel point on the pre-loaded drawing. A more complete description of the functionality of the board and software is presented in the author's research practice report (17). Figure 5 below shows a screenshot from the laptop PC of a circle retrace and the results as displayed by the Accugrid software.

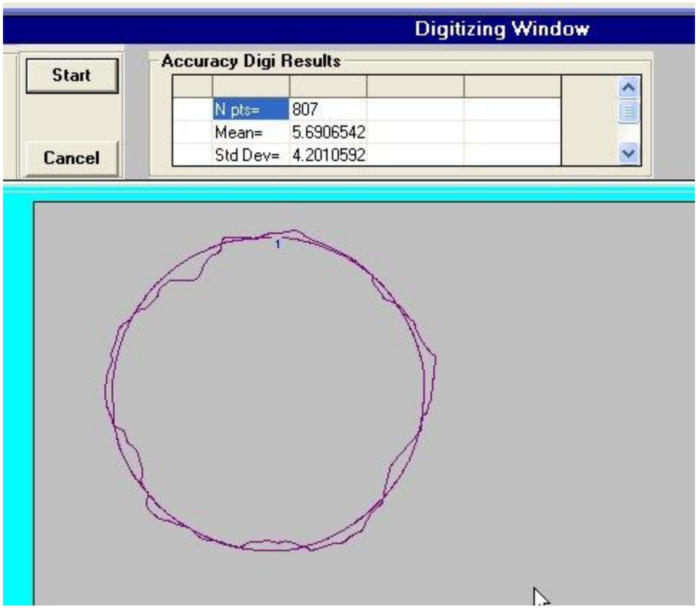


Figure 5: An inaccurate retrace of a presented circle, simulating a child with very poor motor coordination. A mean tracing error of 5.69mm and a standard deviation of 4.20mm can be seen (17).

2.4 Testing procedure and equipment

The complete test program comprised five different tests, both standardized and non-standardized. The Movement ABC-2, the Körper Koordinationstest für Kinder (KTK) and a step-down test to assess femoral control were all standardized tests previously validated in the research literature. In addition we developed two tests specifically for this project; a strength test battery in the slings and the GFTC. This master assignment will focus on results of the intervention as assessed by the M-ABC-2 and the GFTC. The remaining three tests were part of another parallel project and these results will be only briefly discussed.

For the testing procedure the children came in pairs. Height and weight were measured before they were split up to go with each test leader for the two different test-programs: 1) The M-ABC-2 and the proprietary GFTC, and; 2) the KTK, strength tests in the slings and the step-down test. When the children finished testing with one of the test leaders they switched and went through the second test program with the other test leader. The order of testing for each child was identical at pre and post testing. This was to take into account any effects of fatigue.

<u>Movement ABC-2 test</u>

The M-ABC-2 is a standardized testing battery comprising eight different exercises, divided into the three components *Manual Dexterity* (three exercises), *Aiming and Catching* (two exercises) and *Balance* (three exercises). The exercises differ in complexity with child age. For our testing program, two age bands were used with different difficulty: Age band 2 (7-10 years) and age band 3 (11-16 years). During the period two of the children changed age band as they got older, resulting in a more complicated post test than pre test. For more detailed information on the testing procedure, equipment and related data, see Henderson & Sugden (2007).

<u>Week 1 and 2; pre testing</u>

All testing and training took place in a facility at the school premises. It was isolated from the intrusion of other children and had support beams for hanging up Neurac® slings and the large digitizing board. It was also possible to partly isolate the children and test leaders from each other under the two different testing schemes, to avoid any distraction.

Preliminary testing of the 17 subjects was completed over a 14 day period. Four or six children were tested each testing day, depending on their schedule at the school and the availability of the testing facility. One of the children was tested alone. About 90 mins were required for a complete test session with the five different test batteries.

The GFTC comprised three different figures for tracing. Figure 5 below illustrates the three figures permanently sketched on the large digitizing board. The first figure; a circle, was provided as a warmup and not included in the analysis. The second figure; "temple", was drawn twice - both before and after drawing the "star". This design was intended to allow quantification of any acute learning effect during the tracing task. Figure 6 illustrates how the task was performed.

Figure 5: The three figures used for the pre- and post testing on the grapho-motor function test (GFTC).

Figure 6: Tracing task performed standing upright, here examplified by an adult during the pilot testing of the GFTC. The large figure seen was abandoned in favor of two smaller, less complex figures (figure 5) (17).

The test subjects were instructed to position themselves at a given distance from the digitizing board, marked by a piece of tape on the floor. This also put them with their arm and shoulder more or less straight in front of the figure to be traced. Tracing was to be done standing straight up, without leaning and supporting against the board or the wall. Flexing in the knees, hip or back was allowed, as these were considered natural movements when performing such a task.

All subjects were also given the following identical intructions:

- Press the red button on the stylus pen as you start the trace (this was to make sure the complete motion was registerred by the computer).
- Trace as accurately and fast as possible at the same time, without rushing.
- Perform the trace in an even, steady motion.
- Do not stand stiff, but move your body to what feels natural, without changing the position of your feet.

Week 3 - 10; training intervention

After preliminary testing the children trained two sessions a week for eight weeks, each session of about 40 minutes. For the training, as well as the testing, the children came in pairs. Training was conducted on two Redcord® trainers, mounted to crossbeams in the ceiling of the school facility. A 5cm thick foamfilled mat was used on the floor for protection and comfort during the sessions. To make the training more interesting and motivating for the children, a large variation of exerices was used that required the use of both a broad sling on which one can rest the entire body, and standard hand grips. A special coupling was also used that allowed for hooking the broad sling in parallell with the standard grips, such that the entire body could be suspended and unstable during specific training tasks. Special consideration was made to find exercises that were fun for the children and that could incorporate some amount of play. Towards the end of each training session (if the children had behaved), they were allowed to pick for themselves the exercise they found to be the most fun.

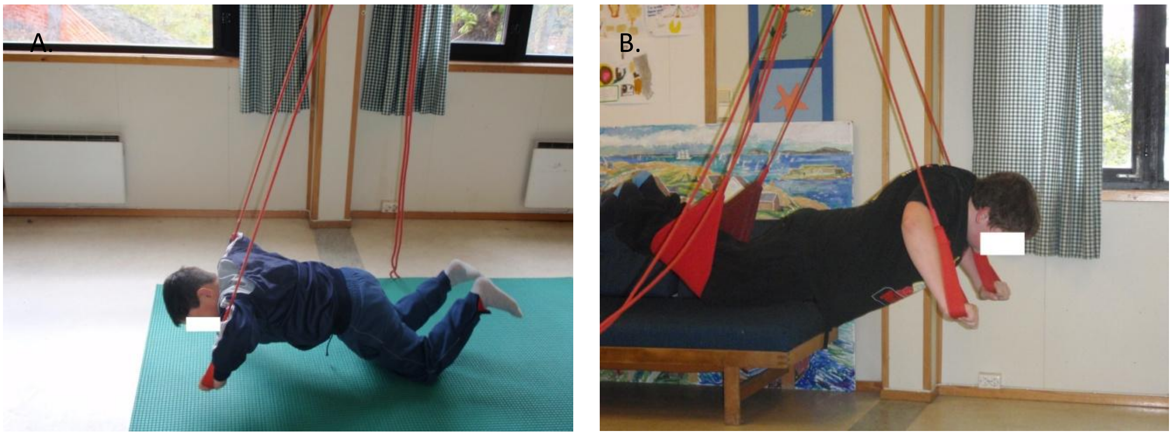
The training program was progressive and increased in difficulty as the training period progressed. For the first week, most exercises started on one of the lowest levels of diffuculty, advancing towards the most difficult levels towards the end of the period, depending on the individual improvement of each child.

Week 11 and 12; post testing

The post testing was conducted in the same manner as the pre testing. Special focus was on arranging the week and testing days as similar as possible to the pre testing run, to avoid any bias. To the extent that it was possible, the same pairs of children were used, at the same day of the week and the same time of the day. After the post testing was complete, both parents and each child was invited to individual meetings/conversations. Here they were informed of the results and/or progress during the intervention, and could discuss any observations they made themselves or any questions that they might have.

Training intervention exercises

Some of the exercises used during the training intervention are examplified below:



Picture 1: Push ups in the slings, simple level on the ground with knees on the mat(a) and advanced level, suspended with sling around lower leg (b).

Picture 2: Laser pen drawing with a laser pen attached to the hand, following figures on the floor as accurately as possible while suspended in the slings (a) and dips with legs on a high pillow (b).

Picture 3: Some of the more playful exercises: Wheelbarrow (a) and walking/skiing (b)

2.5 Statistical analysis

Statistical analysis was conducted using Microsoft Excel 2007 analysis toolkit. Paired Samples T-Test was performed to compare pre and post intervention motor performance. In addition, component score, total score, percentile change and standard deviation were calculated for the M-ABC-2. For the GFTC, mean error, standard deviation and precision score was calculated. A P-value of ≤ 0.05 was considered statistically significant.

3.0 Results

3.1 Movement ABC 2

Results from each of the M-ABC-2 components are presented in table 1, followed by a presentation of individual responses to training (figure 7). On the Manual Dexterity test there was a strong tendency for improvement from pre to post testing, corresponding to a percentile improvement of 9%. However, this was not statistically significant. On the Balance tests there were a stronger and statistically significant improvement, corresponding to a percentile movement for the group from the 37th percentile to the 50th. It can be observed that even though the test subjects are below the 25th percentile on the M-ABC-2 total score, they did not present with markedly reduced balance as a group. Relative improvements were largest in the Aiming & Catching component, with a significant change from the 9th to the 37th percentile. Overall the improvement in the M-ABC-2 corresponded to a significant improvement from the 16th to the 37th percentile, moving the average subject out of the zone for motor control problems.

Table 1: Results from the M-ABC-2, all subjects below 25th percentile. Table shows component score with standard deviation *(SD)*, component score change, percentiles and p-values for the different components. Scoring is standardized from Henderson & Sugden (2007), where a score at the 16th percentile indicates the range between the 9th and the 15th percentile inclusive (yellow zone).

M-ABC-2 Component	Score pre	Score post	Score change	Pctl. pre	Pctl. post	Pctl. change	P-value (score)
Manual Dexterity	22.0 *(6.1)*	25.0 *(3.7)*	3.0 *(5.4)*	16	25	9	0.067
Balance	29.5 *(4.4)*	32.3 *(4.2)*	2.8 *(3.7)*	37	50	13	0.018
Aiming & Catching	13.2 *(3.1)*	16.8 *(5.5)*	3.6 *(4.3)*	9	37	28	0.011
M-ABC-2 TOTAL	64.7 *(7.6)*	74.1 *(8.8)*	9.4 *(8.0)*	16	37	21	0.001

In figure 7 we can see the individual results from the M-ABC-2 total score. The total score is the sum of the scores from the three components of the test; *Manual Dexterity*, *Balance* and *Aiming & Catching*. From the graph it can be seen that all test subjects had moved out of the red zone (at or below 5th percentile) after the training intervention and that only three remained within the yellow zone (between 5th and 15th percentile including). The rest of the children had by definition of the M-ABC-2 moved out of the zone representative of motor control problems (DCD), or the "at risk" group. Five subjects were marginally above this zone before training, as they scored between the 16th and the 25th percentile on the pre test.

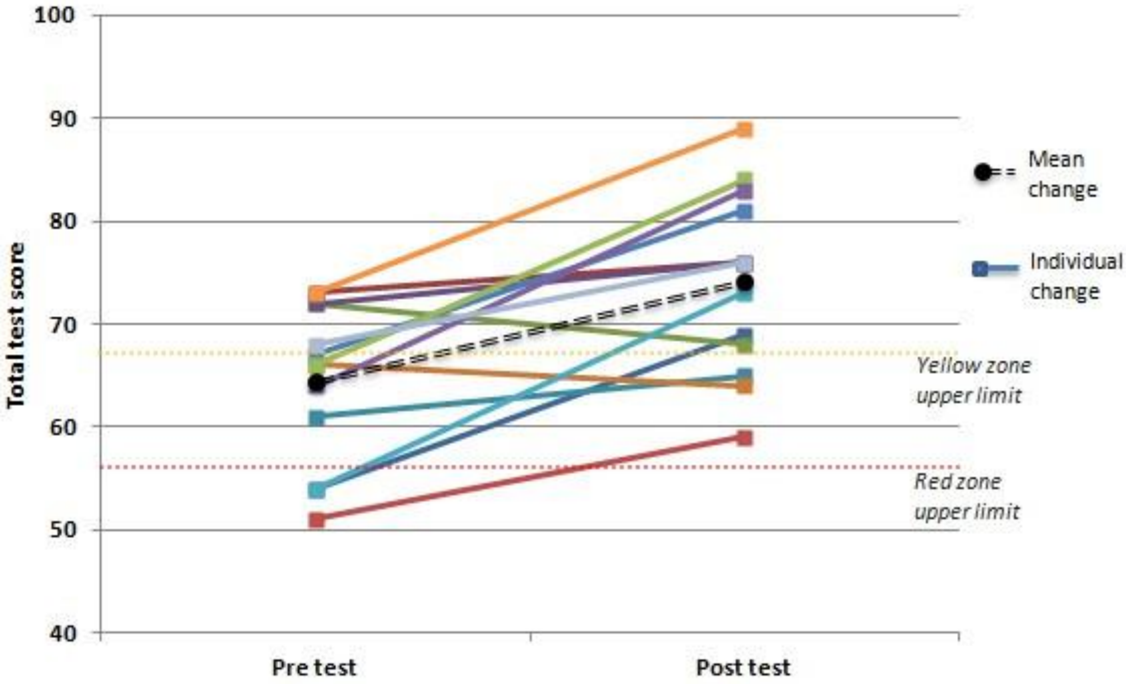


Figure 7: Movement ABC-2 individual responder graph, including mean improvement, all subjects below the 25th percentile.

3.2 Grapho-motor Function Test for Children

The results from the GFTC are presented on the next page. As with the M-ABC-2 analysis were made for all subjects at or below the 25th percentile. The precision score was defined as the mathematical product of accuracy and time, and a lower score indicates a better performance. Figure 8 shows that some of the test subjects had a substantial improvement from pre- to post testing. In particular this applies to subject 1, 8 and 13. On the other hand subject 4 and 11 had a slight lower performance on the post test than on the pre test, and subject 2 and 6 had practically no change. Overall a strong tendency for improvement was found, moving from a precision score of 62.8 to 48.0, but this change did not reach statistical significance (p=0.059). However, a closer analysis of all subjects below the 16th percentile (representative of DCD) revealed a marginally significant improvement of the precision score from 68.3 before the intervention to 47.6 after (p=0.049). An individual responder graph for this is presented in figure 9.

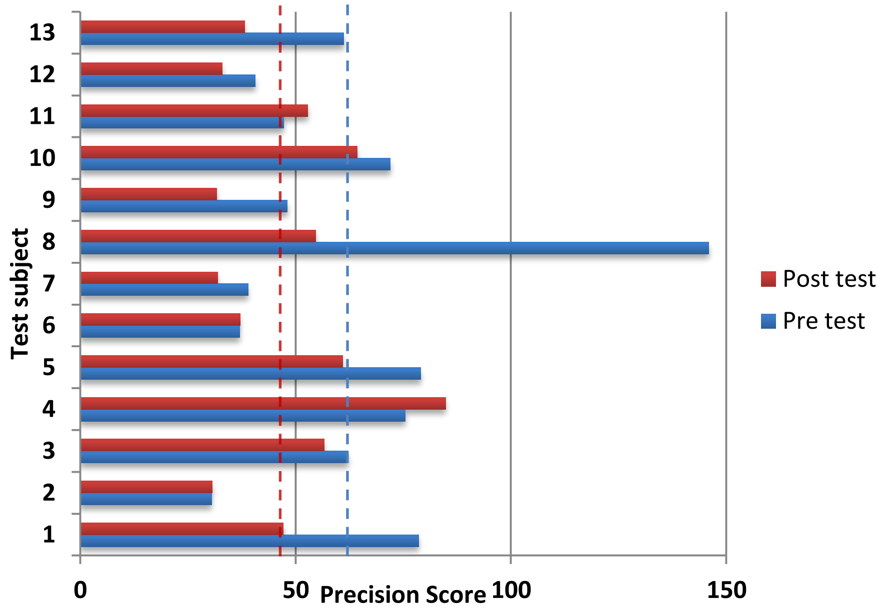


Figure 8: Individual results from the GFTC for all subjects at or below the 25th percentile on the M-ABC-2. Figure includes averages for pre test (blue dashed line) and post test (red dashed line).

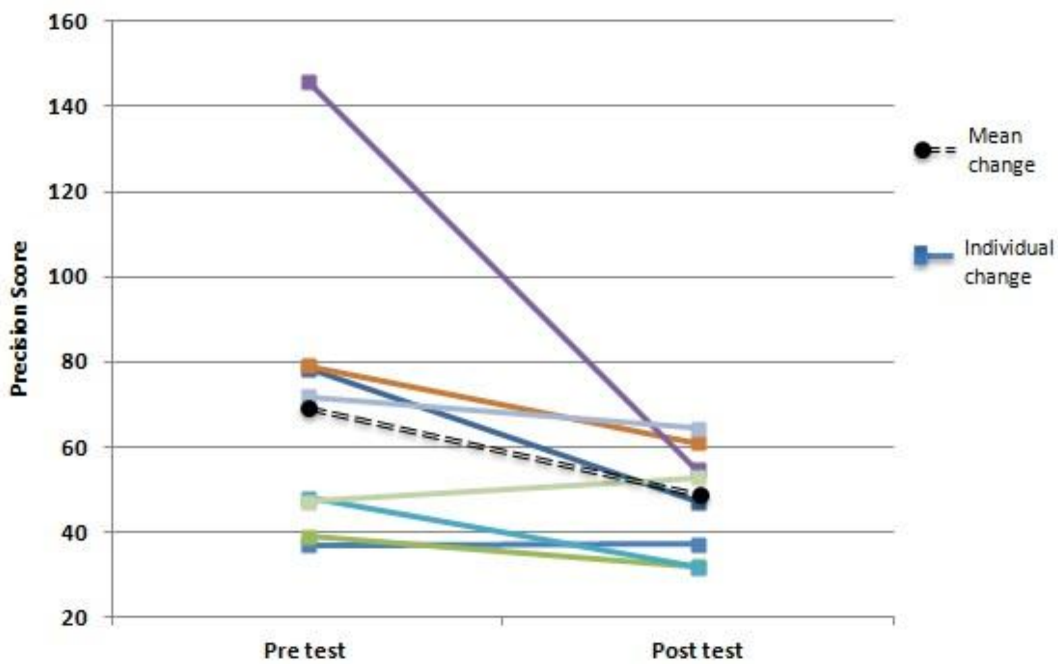


Figure 9: Precision score on the GFTC for all subjects that scored below the 16th percentile on the M-ABC-2. A lower score indicates improved accuracy and speed during the tracing task (p<0.05).

3.3 Qualitative results from observations and interviews

The endpoints for this study were quantitative. However, during the intervention period, the project leaders received a substantial number of unsolicited comments and observations. These were considered relevant in the context of the functional transfer of the training intervention to the daily activities, as well as the emotinal well-beeing of the children.These were noted during the intervention period and some of the more relevant ones are presented below.

Feedback and observations from teachers and staff

I. One of the children had a noticable improvemet in his cycling coordination skills, according to a school staff employee. After the training period this boy had become the second best in a coordinative bicycle contest which involved cycling between obstacles, cones and over wooden boards. He had previously demonstrated considerable problems with maintaining balance on the bike. This boy was among the four not to be included in the analysis, as he was above the 25th percentile.

II. A second boy in the intervention group was also reported having improved cycling skills. One teacher had observed that he was now keeping up with the rest of the class on a cycling trip, without any problems, whereas he before fell quite far behind. This was about 4-5 weeks into the training period. The boy had himself pointed out to the teacher that he believed this to be a result of the sling training.

III. Two teachers gave us feedback on two of the children being more concentrated during classes and also having improved their writing skills. One of these teachers also reported the one boy showing a great deal of entusiasm over the sling training, that he was looking forward to it and telling her how much he was improving. She attributed some of his academical improvements to his sense of achievement and increased self-esteem.

IV. A fourth teacher, dealing with children with special needs, gave us feedback on one boy in our training diagnosed with ADHD. He had become progressively calmer and exhibited less hyperactive behavior in classes, in particular on days where he had been on training.

Feedback from test subjects and test leader observations

I. Test subject 1 had considerable problems with strength and stability in his hip, and was unable to successfully perform the *one leg seat lift* exercise in the sling in the beginning of the period. He performed poorly on all balance tests and seemed to fall without any apparent reason. He showed significant improvement during the training period on the KTK balance tests and the sling training test, but worsened a bit on the M-ABC-2. However, he never fell into the motorically impaired, or "at risk" category. He commented that he had improved well on cycling, becoming the second best in a school cycling contest.

II. Test subject 2 had an overall good improvement on all tests. On the M-ABC-2 pre test he scored at the 16th percentile (yellow group) and improved to the 50th percentile on the post test. During conversations with the test leaders he commented on having improved his skills in the sporst he was regularly active in; shooting harder in handball and "actually hitting the goal" in fotball. His coach had also noticed his improvements.

III. Test subject 3 had been diagnosed with ADHD and was one of the children who distinguished himself the most. He was challenging to work with in the beginning of the period, but as the weeks passed he became gradually more focused and committed. Towards the end of the period he was noticably calmer, working effectively in the training and was one of the children pushing himself the hardest. His motivation had grown a lot and he kept asking for more challenging exercises. His improvement on the KTK and sling tests was formidable, going from 0 push ups in the slings at the beginning of the period to 22 at the end. However, he was without improvement on the M-ABC-2, remaining at the 25th percentile.

IV. Test subject 4 found all the five test batteries problematic, but had a high rate of progress during the entire period. He scored only at the 5^{th} percentile on the M-ABC-2 pre test, but improved to the 37^{th} on the post test - going from being characterized as having severe motor problem to none.

V. Test subject 5 was very skeptical to the training project in the beginning and was quite motorically awkward. He scored at the 5^{th} percentile on the M-ABC-2 pre test and also had substantial problems in the slings and on the KTK. His skepticism dissapated quickly when he noticed a good rate of improvement and when he was encouraged and received positive feedback. On the post test of the M-ABC-2 he scored at the 25^{th} percentile, clearing him of movement difficulties, and he commented that he had become better to keep up on hiking trips and helping at home. On the GFTC he had a strong improvement in precision, from a score of 78.5 to 47.

VI. Test subject 6 demonstrated a lot of problems with upper torso strenght, but also strength in general. He had a high degree of improvement on the sling tests and the KTK, and went from the 25^{th} to the 37^{th} percentile on the M-ABC-2, not indicating any motor control issues. He found the training very motivating and fun, and continuously chose the most difficult and challenging exercises when allowed to pick freely the last exercise of a training session. Generally the kids would choose the exercise they found to be the most playful.

VII. Test subject 7 scored at the 5^{th} percentile on the pre-test of the M-ABC-2 and at the 9^{th} percentile on the post test, moving him from the red to the yellow zone. This was mainly attributed to a substantial improvement from the 5^{th} to the 37^{th} percentile on the Manual Dexterity component. On the other two components there was no significant improvement. Further, he was the child with the highest improvement on the GFTC, going from a precision score of 146.9 to 54.6. Motivationally he also improved a great deal, going from giving up early at relatively light loads to being able to push himself quite hard at the end of the period.

4.0 Discussion

The main objective of this study was to control whether strengthening the core musculature of children with motor control problems would improve their distal control, as measured through the M-ABC-2 and the GFTC. The GFTC was developed specifically for this project with the purpose of measuring distal control through standing drawing; a method not applied before to our knowledge. Our findings suggest that training proximal stabilizing musculature through SET improves both fine and gross motor control in children with motor control problems. Significant changes were observed on the M-ABC-2, moving most of the children out of the zone defined for motor impairment. On the GFTC there was a tendency for moderate improvements in grapho-motor performance. These findings seem to support our hypothesis.

4.1 Movement ABC 2

Overall there was a strong and significant improvement on the M-ABC-2 for all subjects at or below the 25th percentile, which indicated an average change for the group from the 16th to the 37th percentile. All three subjects identified in the red zone on the pre test had moved out of it on the post test. Two improved into the green zone (above 16th percentile), whilst one moved to the yellow. Of the five subjects first identified in the yellow zone, three of them improved to the green zone, whilst two remained. Five subjects were identified at or below the 25th percentile (but above the 16th) and four of these improved to between the 37th and 75th percentile. Most noticeable was the improvements within the components *Balance* and *Aiming & Catching*, with a percentile improvement for the group of 13% and 28% respectively. The change in *Manual Dexterity* component score from 22 to 25 indicated a strong tendency towards improvement, but this was not statistically significant (p=0.067). The significant, overall improvement on the M-ABC-2 suggests that the SET intervention has had a good effect battling these children's motor coordination problems. The training seems to yield best effect on their balance- and upper torso limb coordination skills, as also indicated by strong results on the KTK (39). A closer analysis revealed that the effect of the training was even stronger for the most affected children: For all subjects initially identified in the yellow group there was an improvement from 60.4 on the pre test to 72.3 on the post test, corresponding to a movement from the 9th to the 25th percentile (p=0.003).

Manual Dexterity

Of the three components of the M-ABC-2, *Manual Dexterity* was the only one without statistically significant changes. This might be explained by the fact that a few of the children scored quite well on the pre-testing (50^{th} and 75^{th} percentile), but then worsened on the post testing (37^{th} percentile). As these children were not under the 25^{th} percentile on this component, they bias the results to some extent. Two of the children also aged to the next age band during the intervention period, resulting in more difficult tests on the post testing. This applies in particular to the manual dexterity tests. Additionally the performance variation was higher on this component than the other two. The tendency towards improvement was even stronger for the group at or below the 16^{th} percentile (p=0.057). A closer analysis however, containing only the subjects scoring at or below the 25^{th} percentile on the Manual Dexterity component alone (and not the M-ABC-2 total test score), reveals a significant improvement from the 9^{th} to the 25^{th} percentile. It is therefore reasonable to argue that the sling training has improved the children's manual dexterity abilities as well, bringing them out of the "at risk" category in this area. Two individuals had a very large improvement from the 5^{th} and the 9^{th} percentile to the 37^{th} and 63^{rd} respectively, clearing them of any problems with manual dexterity as per the M-ABC-2.

Balance

For the balance portion of the M-ABC-2 there was a significant increase from pre- to post test, also supported by the results from the KTK (39), suggesting that the sling training has had a good effect on balance. However, only two of the test subjects were below the 16^{th} percentile on the balance component score at the pre test, and only four at or below the 25^{th}, thus suggesting that most of the children had no real balance problems per se. On average they improved from the 37^{th} to above the 50^{th} percentile. The idea that these children did not have any balance problems were not supported by our observations and the feedback we received during the intervention period. One of the test subjects actually scored at the 91^{st} percentile on the pre test of the M-ABC-2 balance component, but had according to school staff and self report, substantial problems with balance, particularly on a bike. He also displayed larger problems with maintaining balance in the slings compared to the other children. After the training intervention he became the second best in a cycling contest at school, due to great improvement of his cycling skills. On the M-ABC-2 balance component however, he deteriorated. Other reports also suggest that the M-ABC-2 is not sensitive enough to reveal light or moderate balance problems, as balance platform tests have indicated significant differences in postural sway between DCD- and TD-children, while no balance problems have been indicated on the Movement ABC (7).

None of the children had a noticeable deterioration during the intervention period, but four remained more or less stationary. Only one of them had a score below the 25th percentile on the post test of this component.

<u>Aiming & Catching</u>

The component of the M-ABC-2 with the highest level of improvement was *Aiming & Catching*. This is perhaps the part of the Movement ABC which can be most closely related to the grapho-motor function test. On average the children that scored at or below the 25th percentile on the M-ABC-2 total score, improved from the 9th to the 37th percentile on the *Aiming & Catching* component. For individuals below the 16th percentile (M-ABC-2 total score), the effect was even stronger, with a change in component score from 12 to 17.1. This corresponded to a percentile movement from the 5th to the 37th percentile. One individual had a dramatic improvement from the 9th to the 75th percentile. This suggests that the sling training intervention has had a good effect for most of the children on tasks requiring precision of upper limb movements during stance. Two individuals deteriorated however, falling from the 25th to the 5th percentile, whilst three remained at or below the 5th percentile without any marked change.

4.2 Grapho-motor Function Test for Children

The GFTC was developed in order to test children's distal control by a grapho-motor drawing task on a digitizing board of high sensitivity. The idea was that the task was to be performed during stance without any kind of support, ensuring reliance on stabilizing musculature throughout the body and not only the shoulder. Part of our hypothesis was that the SET training's positive effect on the children's core musculature would improve their accuracy and speed during an unsupported, standing upright drawing task.

For all subjects at or below the 25th percentile on the M-ABC-2 total score there was a strong tendency towards improvement on the GFTC, but this was not statistically significant ($p=0.059$). This might be explained by the fact that two of the children performed poorer on the post test and that there was a relatively high standard deviation. It is likely that the small number of subjects in the intervention group combined with the large standard deviation caused too much statistical variation, and that a larger group would have resulted in more significant differences. Additionally, a closer inspection revealed that for all subjects below the 16^{th} percentile on the M-ABC-2, despite the low number of subjects, there was a marginally significant improvement from a precision score of 68.3 to 47.6 ($p=0.049$). One test subject had a particularly high improvement from 145.9 on the pre test to 54.6 on the post test. This may indicate that the children that exhibited the greatest motor control problems also improved the most. This is in line with the results from the M-ABC-2, where all subjects below the 16^{th} percentile had an improvement in total score of 11.9, compared to 9.4 for the group as a whole. The most complex figure "star" was the one which yielded the largest and most significant changes. Compared to the "temple" figure which was simpler and had numerous straight lines, the "star" required constant changes in direction during the tracing, and some sudden changes up to about 150°. It may be reasonable to assume that more complex figures, which in turn require more concentration, also are more sensitive to indicate changes in grapho-motor function. Overall, the improvements were a result of both a reduction in the use of time spent, as well as a more accurate tracing.

The figure "temple" was included in the drawing task twice; once before and once after the figure "star" was drawn. This was done in order to check for any acute learning effect that might be present, and was attempted both on the pre and post test. No significant differences were found between the first and second attempt on either test, suggesting that there was no acute learning effect achieved during the drawing task.

The mentioned results support our hypothesis that children's grapho-motor control is improved by training their proximal, stabilizing musculature, a finding which is supported by the observations of improved writing skills reported by several teachers, as well as the children's improved results on the *Aiming & Catching* and *Manual Dexterity* components of the M-ABC-2.

4.3 Qualitative observations and feedback

Throughout the intervention period and the two weeks after, project leaders received feedback from several teachers, the school staff and the children themselves. Most of the feedback was unsolicited and given as noticeable, and seemingly, unexpected changes had been observed. As these reports, yet subjective in nature, concerns the children's quality of life, they may be as important as the quantifiable findings and need to be attributed equal importance.

Two teachers reported two of the children to have improved their writing skills and concentration in classes. This is in line with the unpublished observations by Sandvikmoen, where children after a single training session displayed better posture, less reliance on support and improved writing quality. The observation is also supported by the fact that the children that scored lowest on the M-ABC-2 Manual Dexterity component significantly improved on their drawing- and other manual dexterity subtests, as well as the strong tendency of the group as a whole. One of the teachers contributed the child's improvements in part to be a result of his sense of achievement during the training period, and that he for this reason was less reluctant to write and to participate in class, both in social and scholastic terms.

Two other unsolicited reports were made by another school teacher and one from school staff, regarding two of the children's cycling skills. One of the children had become the second best on a school arranged bicycle contest that required a great deal of balancing and coordination. He had previously shown great difficulties with maintaining balancing on his bike, falling off at several occasions. This observation reinforces the findings of greatly improved balance on the KTK and M-ABC-2, and suggests that the sling training has a positive effect even on the refined balancing skills required to ride a bike - fine improvements that may not appear on the Movement ABC. The other report was made by a teacher who was very enthusiastic about one of the boy's increased stamina on cycling trips. For the first time he was now able to keep up with the rest of the class, and they boy himself pointed out that this was a result of the sling training he had started. During the following training session he sheared his enthusiasm over this experience with the test leaders.

Some of the children reported changes themselves, both unsolicited and when they were asked if they had experienced improvements in any activities. One reported that he was better at helping with heavy tasks at home and that he kept up better on hiking trips, and one reported that he was for the first time able to open the soda caps after his older brother. A couple of the children reported improvements in the sports they were regularly active in; shooting harder in handball and soccer, and "actually hitting the goal". The one boy with the last comment declared that he usually had problems scoring. These observations are supported by the findings of Seiler et. al (2006) and Sæterbakken et. al (2011), demonstrating improvements in sport skills among athletes, and also suggest improvement not only in force but also accuracy.

Other reports were made more in the nature of behavioral and motivational changes. Some of these have been mentioned above, and referred to children being calmer and more concentrated in classes. Another teacher reported one boy to who was formerly very shy and withdrawn to have changed in the social settings in the class. "Suddenly he stood in the classroom telling jokes", participating in social activities and exhibiting a different level of confidence than earlier. Changes similar to these were reported from several of the teachers, though with changes perhaps not this obvious in nature. One child with ADHD were also reported to exhibit less hyperactive impulses and being more focused in classes, especially on days with sling training. These observations support the findings of a study on ADHD children in Drammen, Norway, where they trained SET under a similar regime (9). Motivational and behavioral changes were also noticed by the test leaders, where some of the children who at first gave up easily and were perhaps skeptical, increased their will to push themselves during the period, rid themselves of their skepticism and expressed that they found the training to be fun. Some of the children even started exchanging the most playful exercises with the most challenging ones towards the end of the intervention period, when they were allowed to choose.

Many children with motor control problems are known to suffer from social and behavioral problems, such as anxiety and low self esteem, in addition to learning disabilities and overweight. Many of them shy away from physical activity and other tasks due to their poor motor coordination skills. Thus they often end up being inactive and unfamiliar with sports and motorically challenging activities (3,4,5,38,41). For most of the 17 children included in the training and testing in this project, this period was a completely new experience. A lot of effort was put into making the exercises manageable for all, as well as a positive experience. Emphasis was put on positive feedback, without objective results, and playful and challenging exercises. It seemed as if all the children benefitted from this approach. For many of them the feeling of achievement in physical activity is perhaps more or less unknown. The considerable progress they all experienced, in both tests and training, as well as the experience with positive feedback and a positive relation to a physically challenging activity seem to have contributed to their self-esteem and quality of life. This may be the most important trigger for stimulating a healthier future with more physical activity, besides improving their specific motor control skills and functional strength. In these regards these qualitative observations and the feedback received far exceeded any expectation

4.4 Limitations

This study has several methodological limitations, the most important being the lack of a control group. Another school was originally planned for this, but they withdrew from the project at a time at which it was too late to find other candidates. Without a control group it was not possible to account for any change in motor coordination that might occur from these children's natural development or side activities at school or home that could have triggered such a response. It seems highly unlikely though, that the substantial change witnessed after the short intervention period is caused by such influences. In addition, the fact that there were only 13 subjects used in the analysis may be considered a limitation. The Manual Dexterity component of the M-ABC-2 as well as the GFTC did not yield significant results in some of the analysis, only strong tendencies. Due to the large within group variance it is likely that this would have changed with a larger intervention group.

A second problem is the complete absence of girls in the group. Gender-based differences in childhood development and physiology make it problematic to generalize the changes observed in this study to girls. It is difficult to say anything about their potential for improvement, or whether the effects of this training would manifest itself differently. According to Kaplan et. al (1998) the ratio of boys versus girls with motor control problems should be about 4:1, in which case girls should be represented by at least some individuals in this study. The question can be raised whether girls somehow were neglected in the initial identification process by teachers. Are girls perhaps less observable? It is in the nature of children at this age that boys are more lively and require more teacher attention, whilst girls, and perhaps especially those with challenges, withdraw themselves and are less noticed. It could be that girls with motor control problems for this reason are less identifiable. There may also be an expectation for boys to be more active and more motorically competent than their equally aged piers.

Finally, some comment should be given to the fact that parents and teachers were not by design included in the assessment. The use of a questionnaire, such as the one by Henderson & Sugden (2007), might have proven to give valuable insight into both observable changes as a result of the intervention, as well as their motor coordination status before. All feedback we received in these regards was unsolicited.

4.5 Summary

Significant and positive changes have been demonstrated on all three components of the M-ABC-2 as well as the GFTC. The average child went from being in the yellow "at risk" zone to the green zone, clearing them of any motor difficulties as ascertainable by the Movement ABC. A few of the children demonstrated slight deterioration or remaining stationary over the motor assessment pool. That was in particular noticeable on some of the balance scores. Likely this can to a large extent be attributed to large day-to-day variation normal within children, as well as the know fact that the coefficient of variation on balance platform tests is normally very high (about 40%, which is substantially higher than other fitness tests). It may also be that some of these children's motor control problems are of such a nature that they do not respond on some of the different tests. Response seemed to be more uniform in the KTK and sling testing (39), and it may be that SET training does not stimulate fine motor improvement in all the children, depending on the root of their problems.

There are two unique elements to this study, compared to that of many others. The first is that no motor coordination skills have been trained specifically. The children have carried out a training program for improving core stability and stabilizing musculature, which in turn seems to have a transfer effect both to their gross and fine motor skills. Limitations in the study however, such as the lack of a control group and a low number of test subjects, have made it difficult to draw any definite conclusions.

The second unique element is the implementation of a new testing method for measuring children's grapho-motor function. Surprisingly we were not able to find a standardized test described in the literature that fulfilled our needs, so we developed a new method (17). The GFTC was able to record a drawing/tracing on the digitizing board with a very high degree of accuracy, and then calculate the deviation from the original, preloaded figure, by two unique variables. These were combined with time to give the *Precision Score*. The method was implemented and used in this study without any complications. Improvements in grapho-motor function were comparable to improvements on the M-ABC-2, suggesting that the method has practical value. However due to large variation and a low number of test subjects, results were only marginally significant. It was noticed that the most complex figure "star" indicated the largest changes from pre to post testing, suggesting that the complexity of the figures are highly relevant for the outcome. It may be that the "temple" figure for this group of children was not challenging enough, and that two figures of a more complex design would have revealed more significant changes. For even more motorically challenged children (red group) a more straight-forward type of figures might be more applicable. This claim is supported by the fact that the children that scored below the 16^{th} percentile on the M-ABC-2 were also those who improved the most on the GFTC. There are several aspects of the GFTC development that require further investigation.

While this study was under development another study was performed in Drammen, Norway, with SET training on children with ADHD (9). About half of ADHD-children have been known to suffer from motor coordination problems, but the dynamics of this disorder in combination with motor control problems is still unclear (18). The results indicated that the SET training improved the children's performance on the M-ABC-2, and that individual results could vary a great deal. Some children benefitted a lot from the treatment, whilst others had marginal improvement (9). These findings are similar to that of our study. On initiation of our project the ADHD study was unknown to us.

Several other approaches have been attempted to help children struggling with motor coordination problems, with varying results. They are often classified as either *process oriented*, *task oriented* or *other approaches*. Process oriented approaches aims at underlying processes, such as attention, memory or cognitive function (41). One approach is the Cognitive Orientation to daily Occupational Performance (CO-OP), aimed at problem solving strategies and verbal self-guidance. The method is often referred to as "talking therapy", a sort of self-instructional training. However, there are not currently many studies demonstrating the effect of this treatment, but preliminary results are promising according to Miller et. al (2001). Two task-specific methods worth mentioning is the parent and teacher intervention, as proposed by Sugden & Chambers (2006) and the *Neuromotor Task Training* (NTT) (Niemeijer et. al 2007). The first approach involves both the school and parents to be involved in teaching the children how to best improve specific tasks, such as playing with a ball and writing. Another important factor is that the child itself plays an important role in selecting tasks and goals. It is a time- and resource-consuming intervention, but has demonstrated good results. After the intervention about half of the children never scored below the 5^{th} percentile on the M-ABC-2 again, and about 1/3 improved to above the 15^{th} percentile and never displayed any motor difficulties at a later time. However, some children slipped back to below the 5^{th} percentile after the intervention was ended (42). The second method, Neuromotor Task Training, is a child-centered method that focuses not only on the specific tasks themselves, but also cognitive and psychosocial aspects. These might play an important role for improving the functional motor skills needed in everyday life. This could be factors such as attention, motivation and fear of failure (28). Results from this intervention approach were positive, but as with the parent and teacher intervention, it is a time- and resource-consuming approach requiring a substantial assessment in advance. 10 of 24 children improved equal to or above the 15^{th} percentile on the M-ABC-2, and some children were demonstrated to improve on balance, even though no such task was being trained. Suggestions were made that it could be a result of balance being trained as an intrinsic part of another task, or that improved motivation or self-confidence played a role. It is concluded that the NTT method is effective and that treatment of children with DCD should be task specific (28).

Comparing our approach to the ones mentioned above, it is clear that it is neither in the process nor task oriented category. None of the approaches involve generalized training for a transfer effect to specific tasks requiring fine motor control. However, one popular approach amongst physiotherapists is *sensorimotor integration therapy*. This method presents the child to a number of sensory experiences and propreoceptive feedback, so that this can be integrated into controlled responses. The treatment has demonstrated positive results, and also a transfer effect to other, untreated motor skills (41). Still, the SET method differs significantly with its simplicity and its potential for implementing it in school physical training or in the private sphere of a home. The training principles are easy and quick to learn, and the equipment relatively cheap. Additionally, compared to the two task specific approaches mentioned above, the SET method seems to give better results. In the case of this study only three out of nine test subjects were left below the 16^{th} percentile after the intervention, one of these being a test subject that had improved from the red zone. No test subjects remained below the 5^{th} percentile. It must be mentioned however, that there was no follow-up of these children, and their motor performance after say one year is unknown. The possibility exist that some of them have worsened again, and that training needs to be implemented over a longer time period for changes to be permanent. These are matters that need to be addressed in future research. In any case, the findings of this study demonstrate that the SET method has vast potential, and that intervention in children with motor control problems does not have to be task specific. A combination of this method and a more task specific approach may be worth looking in to. Would the end result be an even stronger synergistic effect?

5.0 Conclusion

There was a significant improvement on the M-ABC-2 total score from pre to post testing. The effect was strongest on the components Balance, and Aiming & Catching, but significant changes were also observed on the Manual Dexterity component for the children who scored at or below the 25^{th} percentile on this specific component. For the GFTC there was a strong tendency towards improvement, which was marginally significant when analyzing all subjects in the yellow zone of the M-ABC-2. A substantial amount of unsolicited feedback was directed at the project leaders during the intervention period, and indicated positive changes in the children's well being, confidence, writing skills, sport skills and other task requiring strength and motor coordination. The absence of girls is a limitation for generalizing the results. Further research should involve a control group, a larger intervention group, which also includes girls, longitudinal follow up and perhaps also inclusion of parents and teachers. Balance tests on balance platform may be advantageous.

It can be concluded that SET training seems to yield significant improvement in motor coordination skills for children identified with motor control difficulties, but further research is required to properly document these effects.

6.0 References

1. Ameratunga, D.; Johnston, L.; Burns, Y. Goal-directed upper-limb movements by children with and without DCD: a window into perceptuo-motor dysfunction? *Physiotherapy Research International (2004) 9, 1, 1-12.*

2. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders (4th ed.).* Washington (DC). American Psychiatric Association; 1994.

3. Cairney, J.; Hay, J. A.; Faught, B. E.; Hawes, R. Developmental coordination disorder and overweight and obesity in children aged 9-14y. *International Journal of Obesity (2005) 29, 369-372.*

4. Cantell, M. H.; Smyth, M. M.; Ahonen, T. P. Clumsiness in Adolescence: Educational, Motor and Social Outcomes of Motor Delay Detected at 5 Years. *Adapted Physical Activity Quarterly (1994) 11, 2, 115-129.*

5. Cantell, M. H.; Smyth, M. M.; Ahonen, T. P. Two distinct pathways for developmental coordination disorder: Persistence and resolution. *Human Movement Science (2003) 22, 4-5, 413-431.*

6. Cherng, R-J.; Hsu, Y-W.; Chen, Y-J.; Chen, J-Y. Standing balance of children with developmental coordination disorder under altered sensory conditions. *Human Movement Science (2007) 26, 913-926.*

7. Deconinck, F. J. A.; Clercq, D. D.; Coster, R. V.; Oostra, A.; Dewitte, G.; Savelsbergh, G. J. P.; Cambier, D.; Lenoir, M. Sensory Contributions to Balance in Boys With Developmental Coordination Disorder. *Adapted Physical Activity Quarterly (2007) 25, 17-35.*

8. Dewey, D.; Kaplan, B. J.; Crawford, S. G.; Wilson, B. N. Developmental coordination disorder: Associated problems in attention, learning and psychosocial adjustment. *Human Movement Science (2002) 21, 5-6, 905-918.*

9. Fysioterapitjenesten for barn og unge. *Intensiv stabilitetstrening av barn med AH/HD.* Drammen. Helsetjenesten Drammen kommune; 2011.

10. Geuze, R. H. Static balance and developmental coordination disorder. *Human Movement Science (2003) 22, 527-548.*

11. Geuze, R. H. Postural Control in Children with Developmental Coordination Disorder. *Neural Plasticity (2005) 12, 2-3, 183-197.*

12. Gillberg, C. Hyperactivity, inattention and motor control problems: Prevalence, comorbidity and background facts. *Folia Phoniatrica et Logopaedica (1998) 50, 3, 107-117.*

13. Gillberg, C.; Kadesjö, B. (2003). Why Bother About Clumsiness? The Implications of Having Developmental Coordination Disorder (DCD). *Neural Plasticity (2003) 10, 1-2, 59-68.*

14. Grove, C. R.; Lazarus, J-A. C. Impaired re-weighting of sensory feedback for maintenance of postural control in children with developmental coordination disorder. *Human Movement Science (2007) 26, 457-476.*

15. Henderson, S. E.; Sugden, D. A. *Movement Assessment Battery for Children-2 (second edition); Examiner's Manual.* London. Pearson Assessment; 2007.

16. Hill, E. L. Non-specific nature of specific language impairment: A review of the literature with regard to concomitant motor impairments. *International Journal of Language and Communication Disorders (2001) 36, 149-171.*

17. Johansen, G. T. Development and relibility testing of a grapho-motor function test for children. Agder University (2009).

18. Jucaite, A.; Fernell, E.; Forssberg, H.; Hadders-Algra, M. Deficient coordination of postural adjustements during a lifting task in children with neurodevelopmental disorders. *Developmental Medicine and Child Neurology (2003) 45, 731-742.*

19. Johnston, L. M.; Burns, Y. R.; Brauer, S. G.; Richardson, C. A. Differences in postural control and movement performance during goal directed reaching in children with developmental coordination disorder. *Human Movement Science (2002) 21, 583-601.*

20. Kadsjo, B.; Gillberg, C. Developmental coordination disorder in Swedish 7-year-old children. *Journal of the American Academy of Child and Adolescent Psychiatry (1999) 38, 7, 820-828.*

21. Kaplan, B. J.; Wilson, B. N.; Dewey, D.; Crawford, S. DCD may not be a discrete disorder. *Human Movement Science (1998) 17, 4-5, 471-490.*

22. Miller, L. T.; Polatajko, H. J.; Missiuna, C.; Mandich, A. D.; Macnab, J. J. A pilot trial of a cognitive treatment for children with developmental coordination disorder. *Human Movement Science (2001) 20, 183-210.*

23. Miyahara, M.; Piek, J. P.; Barrett, C. Effect of postural instability on drawing errors in children: A synchronized kinematic analysis of hand drawing and body motion. *Human Movement Science (2008), doi: 10.1016/j.humov.2008.03.001.*

24. Moe, K., Thom, E.; Musculoskeletal disorders and physical activity. Results of a long-term study. *Journal of the Norwegian Medical Association (1997) 29, 42 58-61.*

25. Moseley, G. L.; Hodges, P. W. Are the Changes in Postural Control Associated With Low Back Pain Caused By Pain Interference? *The Clinical Journal of Pain (2005) 21, 4, 323-329.*

26. Moseley, G. L.; Hodges, P. W. Reduced variability of postural strategy prevents normalization of motor changes induced by back pain: a risk factor for chronic trouble? *Behavioral Neuroscience (2006) 120, 2, 474-476.*

27. Muceli, S., Farina, D., Kirkesola, G., Katch F., Falla D.; Reduced force steadiness in women with neck pain and the effect of short term vibration. *Journal of Electromyography & Kinesiology (2010) 21(2), 283-90.*

28. Niemeijer, A. S.; Smits-Engelsman, B. C. M.; Schoemaker, M. M. Neuromotor task training for children with developmental coordination disorder: a controlled trial. *Developmental Medicine and Child Neurology (2007) 49, 406-411.*

29. Pettit, L.; Charles, J.; Wilson, A. D.; Plumb, M. S.; Brockman, A.; Williams, J. H. G.; Mon-Williams, M. Constrained action selection in children with developmental coordination disorder. *Human Movement Science (2008) 27, 286-295.*

30. Redcord Inc. *Neurac® therapy*. Redcord; 2008. 40 pages.

31. Rosenblum, S.; Livneh-Zirinski, M. Hand writing process and product characterstics of children diagnosed with Developmental Coordination Disorder. *Human Movement Science (2008) 27, 200-214.*

32. Saliba, S. A., Croy, T., Guthrie, R., Grooms, D., Weltman, A., Grindstaff, T. L.; Differences in transverse abdominis activation with stable and unstable bridging exercises in individuals with low back pain. *North American Journal Of Sports Physical Therapy (2010) 5(2), 63-73.*

33. Schmoll, S., Hahn, D., Schwirtz, A.; Die Behandlung von chronischenm LWS-Smerz mithilfe des S-E-T-Konzeptes (Sling-Exercise-Therapy). *Bewegungstherapie und Gesundheitssport (2008) 24, 1-8.*

34. Seiler et. al.; Sling Exercise Training improves balance, kicking velocity and torso stabilization strength in elite soccer players. *Medicine & Science in Sport & Exercise (2006) 38(5), p243.*

35. Seiler, S., Skaanes, P. T., Kirkesola, G.; Effects of Sling Exercise Training on maximal clubhead velocity in junior golfers. *Medicine & Science in Sports & Exercise (2006) 38(5), p286.*

36. Seiler, S., Sæterbakken, A.; A Unique Core Stability Training Program Improves Throwing Velocity in Female High School Athletes. *Medicine and Science in Sports and Exercise (2008) 40 (5, supplement), p25.*

37. S-E-T Grunnkurs: En innføring I Sling Exercicise Therapy

38. Skinner, R. A.; Piek, J.P. Psychosocial implications of poor motor coordination in children and adolescents. *Human Movement Science (2001) 20, 1-2, 73-94.*

39. Sola, A. K. J.; Hvilken effekt har slyngetrening på de motoriske ferdigheter hos barn med Developmental Coordination Disorder? Agder University (2010).

40. Stuge, B., Lærum, E., Kirkesola, G., Vøllestad, N.; The Efficacy of a Treatment Program Focusing on Specific Stabilizing Exercises for Pelvic Girdle Pain After Pregnancy. A Randomized Controlled Trial. *Spine (2004) Vol. 29, Nr. 4, p 351-359.*

41. Sugden, D. A.; Chambers, M. E. Intervention approaches and children with developmental coordination disorder. *Pediatric Rehabilitation (1998) 2, 4, 139-147.*

42. Sugden, D. A.; Chambers, M. E. Stability and change in children with Developmental Coordination Disorder. *Child: Care, health and development (2006) 33, 5, 520-52.*

43. Sæterbakken, A. H., Van Den Tillaar, R., Seiler, S.; Effect of core stability training on throwing velocity in female handball players. *The Journal of Strength and Conditioning Research (2011) 25(3), 712-18.*

44. Tsauo, J. Y., Cheng, P. F., Yang, R. S.; The effects of sensorimotor training on knee proprioception and function for patients with knee osteoarthritis: a preliminary-report. *Clin Rehabil (2008) 22, 448.*

45. World Health Organization; *The ICD-10 Classification of Mental and Behavioural Disorders: Clinical descriptions and diagnostic guidelines.* Geneva. World Health Organization; 1992.

46. Williams, H. G.; Fisher, J. M.; Tritschler, K. A. Descriptive analysis of static postural control in 4, 6, and 8 year old normal and motorically awkward children. *American Journal of Physical Medicine (1983), Vol. 62, No. 1, 12-26.*

47. Willson J. D, MSPT, Dougherty C. P, DO, Ireland M. L, MD, Davis I, M, PhD, PT: Core stability and its relationship to lower extremity function and injury. *Journal of the American Academy of Orthopaedic Surgeons (2005) 13, p 316-325.*

Appendix 1

Til foreldre/foresatte til [navn]

Invitasjon til foreldremøte onsdag 25/2

Vi viser til tidligere telefonsamtale med skolen og takker for imøtekommenhet og interesse. Vi ønsker derfor å invitere til foreldremøte på ………. skole onsdag 25/2 kl 18:00.

Tema på foreldremøte vil være forskningsprosjektet ”slyngetrening og motorisk funksjon hos barn” i regi av Institutt for helse og idrett ved universitetet i Agder (UiA). Prosjektet omhandler en lovende treningsmetode som universitetet mener kan ha positiv effekt på motorisk funksjon hos barn.

For å få gjennomført prosjektet er universitetet avhengig av at flest mulig kan delta, så vi håper derfor du/dere har anledning å stille på møtet.

Med vennlig hilsen

[sign]

Inspektør, …….. skole

[sign]

Dr. Stephen Seiler
Professor, institutt for helse og
Idrett, universitetet i Agder.

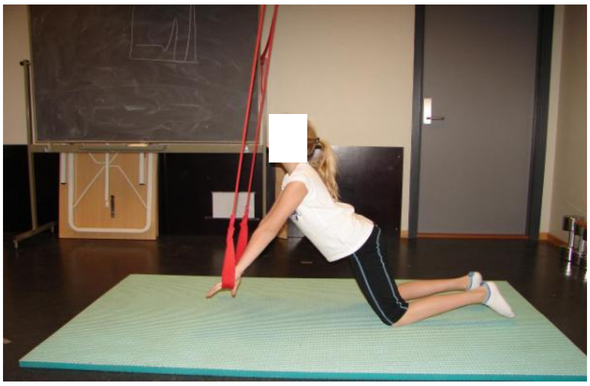
Appendix 2

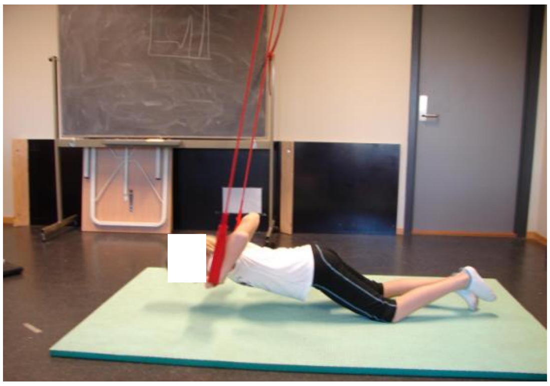
Forespørsel om barnets deltakelse i forskningsprosjektet

”Har slyngetrening en positiv innvirkning på motoriske ferdigheter hos barn?”

Bakgrunn og hensikt
Dette er en forespørsel om å tillate ditt barns deltakelse i et forskningsprosjekt i regi av fakultet for helse og idrettsfag ved universitetet i Agder. Prosjektet gjennomføres av to mastergradstudenter og deres veiledere, i samarbeid med skolen. Prosjektet skal evaluere effekten av et enkelt motorisk treningsprogram. Programmet består av en rekke utfordrende øvelser som ved hjelp av ustabile slynger stimulerer og utvikler funksjonell styrke og kontroll av stabiliserende muskulatur primært rundt hofte, rygg og skuldre. Forhåpentligvis vil treningen også kunne bidra til å forbedre barnets motorikk. Ditt barn er identifisert som en potensiell deltaker i prosjektet, basert på erfaring gjort kroppsøvingslærer og kontaktlærer.

Hva innebærer studien?
Vi vil starte prosjektet med å gjennomføre motorikktester som er designet for å måle evner som balanse, hopping, mottak og kast av ball, samt finmotorikk som fingerferdighet og evne til å nøyaktig tegne/spore sammensatte figurer. Barna vil bli testet individuelt, og det enkelte barn vil motta oppmuntring og positiv tilbakemelding, men ikke spesifikke resultater fra testene. Disse kan dere som foresatte få, om ønskelig. Etter testingen vil barna delta i aktivitetsprogrammet hvor de to ganger i uken trener i Redcord slyngesystem. Etter åtte ukers trening vil vi pånytt gjennomføre de samme testene for å evaluere hvorvidt denne metoden har hatt en positiv effekt for barna.
En av testene er en balansetest som innebærer at barnet blir filmet (kun fra hofte og ned). Dette er kun for og i ettertid kunne gjennomføre evaluering som vil være vanskelig å gjøre direkte i situasjonen. Opptakene vil kun bli benyttet og evaluert av autorisert personell tilknyttet studien, og alle resultater anonymisert.





(bildene illustrerer push-ups gjort i Redcord-slyngene)

Mulige fordeler og ulemper

Treningen og testingen vi vil gjøre er enkel, utfordrende og morsom for barna. Utprøving gjort på en liten gruppe barn tyder på at forbedring av funksjonell styrke og kontroll over stabiliserende muskulatur gjennom slyngetrening kan lede til forbedringer i kroppsholdning, samt forbedring i ferdigheter som balanse, kast og mottak, koordinasjon, og også skriveferdighet. Så den potensielle nytteverdien av treningen er positiv. Aktivitetsprogrammet vil bli integrert i skole og/eller SFO-tiden. Det er ingen risiko, ubehag eller bivirkninger assosiert med verken treningsprogrammet eller testingen, utover mulig ”stølhet” i muskler etter trening som er uvant. Det vil også bli lagt vekt på å unngå enhver form for tilbakemelding som kan resultere i sammenligning av prestasjonen barna imellom.

Hva skjer med informasjonen om mitt barn?

Informasjonen som registreres om ditt barn skal kun brukes slik som beskrevet i hensikten med prosjektet. Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte opplysninger som kan identifisere ditt barn. En kode knytter barnet til deres opplysninger gjennom en navneliste. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten. Eventuelt formidling av resultatene vil kun være basert på gruppen som helhet og går ikke på individnivå.

Frivillig deltakelse
Det er frivillig å delta i studien. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke for barnets deltakelse i studien. Dette vil ikke få konsekvenser for barnet. Dersom du ønsker å tillate barnets deltakelse, undertegner du samtykkeerklæringen på siste side. Dersom du senere ønsker å trekke deg eller har spørsmål til studien, kan du kontakte Professor Stephen Seiler, Universitet i Agder, Stephen.seiler@uia.no, 38141347, eller rektoren på din skole.

Tidsskjema

Tenkt tidsplan for perioden:

Uke 8 – 9 *Pre-test periode*	Uke 10 *Vinter ferie*	Uke 11 – 14 *Intervensjon del 1*	Uke 15 *Påskeferie*	Uke 16 - 19 *Intervensjon del 2*	Uke 20 – 21 *Post-test periode*

Appendix 3

Samtykke til deltakelse i studien

Jeg er villig til å la mitt barn delta i studien

(Signert av foresatte, dato)

Stedfortredende samtykke når berettiget

(Signert av nærstående, dato)

Jeg bekrefter å ha gitt informasjon om studien

(Signert, rolle i studien, dato)

Appendix 4

Til foreldre/foresatte til

Invitasjon til foreldremøte onsdag 17/6

Treningsperioden med slyngetrening er nå over og testingen er avsluttet. Vi takker for at dere har deltatt og ønsker derfor å invitere til foreldremøte på ……… skole onsdag 17/6 kl 18:00.

På foreldremøte vil vi oppsummere treningsperioden, bla med tanke på resultatene som er oppnådd, hvordan elevene har opplevd perioden, og hvordan dere som foreldre har opplevd dette. Vi ønsker gjerne tilbakemelding fra dere, både med ros og ris.

Vi håper dere kan ta dere tid til å stille på møtet, og på forhånd tenke gjennom hvordan dette har påvirket deres barn og eventuelt dere.

Med vennlig hilsen

Inspektør, ………… skole

Geir Johansen og Anne K. Sola
Mastergradstudenter, institutt for helse og Idrett, universitetet i Agder.