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HIGH-LEVEL MOBILITY IN ADULTS WITH TRAUMATIC BRAIN INJURY AND ADULTS BORN WITH VERY LOW BIRTH WEIGHT

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Contents

Abbreviations

CI	Confidence Interval
CNS	Central nervous system
CP	Cerebral palsy
DAI	Diffuse axonal injury
EEG	Electroencephalography
GCS	Glasgow Coma Scale
GOSE	Glasgow Outcome Scale Extended
HiMAT	High-level Mobility Assessment Tool
HISS	Head Injury Severity Scale
MRI	Magnetic resonance imaging
NICU	Neonatal intensive care unit
OR	Odds ratio
PVL	Periventricular leukomalacia
PTA	Posttraumatic amnesia
SES	Socioeconomic status
SD	Standard deviation
TBI	Traumatic brain injury
VLBW	Very low birth weight

Abstract

Background and aim: Persons sustaining different types of brain injury may experience difficulties with advanced mobility. Both persons with traumatic brain injury (TBI) and persons born with very low birth weight (VLBW) have similar brain abnormalities, such as reduced white matter and connectivity, and may thus experience similar mobility problems. However, few studies have assessed advanced motor abilities, and none have compared mobility functions in adult TBI and VLBW populations. Our aim was to investigate high level mobility functions in adults with TBI and VLBW adults compared to matched controls, and to compare high-level mobility in TBI and VLBW adults.

Methods: Participants consisted of 22 subjects (mean age 22.9 ± 2.0 yrs) with chronic traumatic brain injury, and 35 subjects (mean age 22.5 ± 0.7 yrs) born preterm with birth weight (below 1500 grams). Two TBI participants were not able to complete all test items due to pain. The VLBW group included three subjects with cerebral palsy (CP). Each group was matched with its own control group, consisting of 24 subjects each from the same geographical area matched by age and sex. Mean age in the control group was 23.3 ± 1.8 yrs for TBI and 22.8 ± 0.5 yrs for VLBW. Advanced mobility functions were assessed by the High-level Mobility Assessment Tool (HiMAT), which consists of 13 timed mobility tasks, with a maximum total HiMAT score of 54.

Results: Mean total HiMAT score in the TBI group was 47.0 ± 7.7 compared to 50.3 ± 3.9 for the controls (U=193, p=0.116). Three of 13 mobility tasks differed significantly from the control group: ‘walking’, ‘walk over obstacle’ and ‘bound non-affected leg’. When the two subjects who reported pain were excluded from the analysis, mean total HiMAT score was 48.9 ± 4.9 (U=193, p=0.264), with ‘walking’ and ‘walk over obstacle’ remaining significantly different from the control group. In the TBI group, nine (40.9%) participants performed at or below the 5^{th} percentile compared to 6 (25%) of the TBI controls. Mean total HiMAT score in the VLBW group was 45.1 ± 7.8 compared to 49.9 ± 3.5 in its control group (U = 256, p=0.011). Five of the 13 mobility task scores were significantly different from the control group: ‘walking backwards’, ‘running’, ‘hop affected leg’, ‘bound affected leg’, and ‘bound non-affected leg’. When the three subjects with CP were excluded, mean total HiMAT score was 46.8 ± 5.5 in the VLBW group (U=256, p=0.033) and three mobility task scores remained significantly different from the controls: ‘walking backwards’, ‘hop affected leg’ and ‘bound

non-affected leg'. In the VLBW group, 17 (48.6%) participants performed at or below the 5th percentile compared to 4 (16.7%) of the VLBW controls. When directly compared to the VLBW group, the TBI group had (OR 0.733, CI 0.249 – 2.154) lower risk for performing at or below the 5th percentile, although not significant.

Conclusions: Compared to controls, adults with TBI had reduced high-level mobility in specific tasks. Adults born with VLBW had reduced overall high level mobility. Furthermore, the HiMAT seems to be a valuable tool for assessing high-level mobility in VLBW populations, and should be formally tested for further use.

Keywords: High-level mobility, high-level mobility assessment tool, traumatic brain injury, very low birth weight

1. Introduction

Independent mobility is an essential part of daily life functioning and has substantial consequences for social participation, academic performance, work capacity, leisure activities, and quality of life. Advanced mobility refers to gross locomotor abilities important for accomplishment in essential daily life tasks, such as running, hopping, and skipping (Williams and Morris, 2009, Williams et al., 2004). Although there exists a wide variety of mobility forms, research has mainly focused on kinematic, kinetic, and EMG characteristics of unobstructed, straight-line walking (Sutherland et al., 1980). Gait development in children and gait alterations seen in the elderly population have been the most important in research (Wollacott and Horak, 1992). Other forms of mobility are more rarely reported, and there is a noticeable gap in the literature concerning advanced mobility function in young adults.

Mobility is likely to be influenced by brain damage. Consequently, the experience of a brain injury may result in a range of sequelae, such as cognitive, attentional, and socialization deficits, as well as life-long motor and behavioral impairments. (Khan et al., 2003, Volpe, 2009b, Yeates et al., 2005). Furthermore, brain injuries can occur at different stages of life, such as pre- and perinatal injuries, or as a trauma at later ages. Due to different injury mechanisms, early or late occurring brain injuries can result in differences in mobility outcome, but also important common features may appear as well.

Depending on when the brain injury occurs, the central nervous system may have different strategies available to allow for recovery from the injury. The perinatal brain has the advantage of enhanced neuronal plasticity mechanisms in the first years of life when the brain is still developing (Johnston, 2009). Functional and structural changes due to adaptive plasticity are beneficial to improve function, and reorganization of the brain's motor and sensory maps, in addition to activity-dependent plasticity across synapses, is the principal mechanism for adaptive plasticity after brain injury. Furthermore, activation across synapses is determined by the frequency and strength at which the synapses are being used (Johnston, 2009). In brain injuries occurring as a trauma at later stages of life, cortical reorganization is an important recovery mechanism from neural damage (Kimberley et al., 2010, Ramanathan et al., 2006). Reorganization may occur as formation of new synapses, or as increased activity in existing synapses (Brodal, 2007). Recent studies highlight both synaptic neurotransmission and non-synaptic activity to have substantial importance in recovery from traumatic brain injury (TBI) (Bach-y-Rita, 2003). Both recovery mechanisms in the premature young brain

and in the older mature brain seem to be beneficial, but the effects of early versus late brain injury with respect to long-term mobility outcome are largely unknown.

A common form of brain damage among young adults is TBI, which is defined as *"an alteration in brain function, or other evidence of brain pathology, caused by an external force"* (Menon et al., 2010, p 1637) e.g. hitting the head in a traffic accident or fall. The incidence of TBI in Europe is 235/100 000 per year, including both hospitalized and fatal TBI (Tagliaferri et al., 2006). In Oslo, the incidence is found to be 83/100 000 per year (Andelic et al., 2008). However, due to non-reported TBI and the existence of a variety of criteria used to estimate incidence, the exact annual incidence rate of TBI is not well documented (Andelic et al., 2008).

TBI can be either diffuse, focal, or a combination of the two mechanisms. Diffuse axonal injury (DAI) is the most common type of injury, and occurs most commonly in corpus callosum, brain stem, and cortical white matter (Arfanakis et al., 2002). DAI is described as a shear-strained deformation of the brain causing a change in the brain's shape (Arfanakis et al., 2002), due to acceleration, deceleration, or rotation of the brain (Caeyenberghs et al., 2011). Depending on the presence and level of consciousness after the trauma, a TBI may be characterized as mild, moderate or severe (Skandsen et al., 2010).

Various motor-related deficits, and short and long term impairments are reported across all degrees of TBI. Sosnoff et al. (2008) reported impaired balance and postural control, in addition to increased reaction time in persons with mild TBI 24 hours post-injury. Andelic et al. (2010) reported less independency in motor function and activity one year after injury in 26% of their adult TBI group (16-55 yrs), suffering from moderate to severe TBI. Furthermore, examining adult TBI patients with mild, moderate, and severe injury, Hillier et al. (1997) detected upper limb deficit (30%), gait alterations (24%), and impaired balance (34%) five years after trauma. In TBI patients at 30-52 years of age, Chou et al. (2004) found shorter stride length, decreased walking speed, and increased sideways sway in all severities of TBI, two to 15 years post injury. The increased sideways sway reflects difficulties maintaining dynamic balance, which is a symptom often reported by TBI patients even a long time after injury (Chou et al., 2004).

In infants, a common cause of brain injury is related to being born with very low birth weight (VLBW) (Volpe, 2009a). These infants are born before the 37^{th} week of gestation with a birth weight below 1500g. VLBW constitutes 1% of all live births in Norway (Medical Birth Registry of Norway, 2009), and the number of preterm survivors has increased over the past decades due to advanced neonatal care (Balakrishnan et al., 2011, Evensen, 2010).

Periventricular leukomalacia (PVL) refers to focal or diffuse cerebral white matter damage (Volpe, 2009a), and is the most common type of brain injury in prematurely born infants (Inder et al., 1999, Nagae et al., 2007). Brain injury and developmental problems are highly common among VLBW survivors, and problems are often related to cognitive, behavioral, attentional, and perceptual deficits, and motor disability (Skranes et al., 2005, Volpe, 2003, Volpe, 2009a). Cerebral palsy (CP) is known as the most severe motor sequelae (Anderson et al., 2005), occurring in 5-10% of children born with VLBW (Volpe, 2009a). Furthermore, Evensen (2010) reported less severe motor deficits in one out of every five VLBW children.

VLBW populations consistently demonstrate motor delay during the first months and years of life. Furthermore, motor problems such as reduced balance, manual dexterity, and ball skills have been persistently reported in both VLBW children and adolescents (Evensen, 2010). In a recent meta-analysis by de Kieviet and colleagues (2009), poor fine and gross motor skills were found in a total of 23 studies in VLBW children at six to 36 months of age. The same meta-analysis reported poorer balance, ball skills, and manual dexterity than controls in four studies on VLBW children five to eight years of age, using the Movement Assessment Battery for Children (Movement ABC) (de Kieviet et al., 2009). Furthermore, using the Bruiniks-Oseretsky Test of Motor Proficiency (BOTMP), a total of 37 studies reported poorer overall motor function in persons born with VLBW compared to controls born at term (de Kieviet et al., 2009). The BOTMP subscales include tasks assessing running speed and agility, balance, bilateral coordination, strength, upper limb coordination, response speed, visual motor control, and upper limb speed and dexterity.

Although individuals with TBI or VLBW suffer from different injury mechanisms, injury type and outcome can show remarkable resemblance. Both groups show white matter damage (Skandsen et al., 2010, Vangberg et al., 2006), which may imply reduced connectivity in the brain and lead to motor problems in executing tasks requiring fine and/or gross motor function. Furthermore, reduced fine and gross motor functions are frequently reported in both groups, and deficits related to balance and postural control are the most prevailing gross motor impairment in both groups. For both persons with TBI or VLBW, returning to work or studies, participation in sports and leisure activities, and social activities will depend on recovery from the brain injury, as regaining of advanced mobility function is important for accomplishment of daily life activities. In VLBW populations, there is an evident lack of appropriate tests to examine advanced mobility function. For TBI populations, the most

frequently used mobility outcome measures often fail to challenge high-level mobility, which is required in order to return to pre-injury activities (Williams et al., 2004).

The current study focuses on advanced mobility in young adults with possible late or early brain damage. There are very few tools available to test advanced mobility in adults, but the recently developed High-level Mobility Assessment Tool (HiMAT) (Williams et al., 2005b) is considered a valuable contribution. The HiMAT includes tasks such as fast walking, running, walking in stairs, walking backwards and on toes, the ability to negotiate an obstacle, as well as hopping, skipping, and jumping forward from one foot to the other. The HiMAT was developed specifically to assess high-level mobility in persons with TBI and is recognized as a valid tool in this group (Williams et al., 2006, Williams et al., 2005b), but has not yet been used as an assessment tool in persons born with VLBW. However, Williams (2004) argues that the HiMAT might be a suitable tool for other neurological conditions in adults as well, such as stroke or Parkinson's disease.

Due to the above-mentioned similarities in injury type and injury outcome, it is of emerging interest to explore high-level mobility functions in young adults with possible early versus late brain injury. To the best of my knowledge, this is the first study that assesses high-level mobility in adults with TBI and adults born with VLBW, and compares this to controls.

The current study focuses on the following research questions:

- Do persons with TBI and VLBW have reduced overall high-level mobility?
- Do persons with TBI and VLBW have different problems related to high-level mobility?

2. Methods and Material

2.1 Design

This double case control study is based on two larger longitudinal follow-up studies: "Advanced MRI for diagnosis and outcome assessment in patients with traumatic brain injury (TBI)" and "Low birth weight in a lifetime perspective" (Indredavik et al., 2004, Evensen et al., 2004) at the Faculty of Medicine, NTNU. The present study involves an adult group with TBI and an adult group born with VLBW, each matched with its own control group. Data included in the present study were collected between June 2009 and September 2010.

2.2 Participants

From the larger data sets, young adults between 21 and 25 years of age were included as participants in the present study. In the original larger studies, control groups for VLBW and for TBI were matched on different variables. Therefore, the control groups are described and analyzed separately.

2.2.1 TBI group

The TBI group consisted originally of 70 participants, age ranging from 16 to 65, with chronic traumatic brain injury admitted to St. Olav's Hospital from October 2004 to October 2007. The participants were examined with a neuropsychological test battery three, six and twelve months after injury, and MRI examinations were performed within the first four weeks, and at three and twelve months after injury. For the current study, 22 participants (15 men and 7 women), were examined in the chronic phase (one year or more after injury). See Table 1 for age, anthropometrical measures, and general background variables at follow-up.

2.2.2 TBI control group

The TBI control group consisted originally of 65 healthy participants from the same geographical area matched by age, sex and education. Controls were recruited among family and social networks of the TBI participants and hospital employees, and by contacting suitable work places for educational matching. Age was matched within five year intervals. To control for socioeconomic status, highest completed education was chosen. Twenty-four healthy controls (18 men and 6 women) were included (Table 1). Of these, 12 controls were

originally recruited to function as controls for both TBI and VLBW participants, but since this study involves both groups, they were included only in the TBI control group in the present study.

2.2.3 VLBW group

The VLBW group consisted of 35 participants (14 men and 21 women), born before 37th week of gestation with birth weight below 1500 grams (Table1). The group included three participants with CP, of which two males had diplegia and one female had hemiplegia. Participants had been admitted to the neonatal intensive care unit at St. Olav's Hospital between 1986 and 1988, and participated in the larger longitudinal follow-up study.

2.2.4 VLBW control group

The VLBW control group consisted of 36 participants from the same geographical area (Trondheim) matched to the VLBW group by age and sex. The controls were term-born and participated in the same follow-up study as the VLBW participants. They were born to mothers enrolled before week 20 of their pregnancy in a study on causes and consequences of intrauterine growth restriction (Vik et al., 1997). Since 12 of these participants were also part of the control group for TBI in the larger study, they were excluded from the VLBW control group in the current study. The remaining 24 participants, 6 men and 18 women, are described in Table 1.

2.3 Background variables

Prior to testing, anthropometric measures were taken and basic background variables were registered in a brief structured interview (Appendix 1). Weight was measured on an electronic scale (to nearest 10 grams). Height was self-reported or measured with measure tape. From these two measures body mass index (kg/m2) was calculated. Head circumference was measured to the nearest 0.1 cm.

Education was registered in years and dichotomized into < 12 years and ≥ 12 years. Current illnesses and injuries that could affect test results were also reported. Pain was reported with VAS (Visual Analogue Scale) on a scale from 0 (no pain) to 10 (worst pain imaginable) (Appendix 1).

2.4 Group-specific variables

2.4.1 TBI

Glasgow Coma Scale (GCS) was used to assess initial level of consciousness by evaluating eye, motor and verbal response into a range of 3-15 points. The results from GCS were categorized into mild (≥13 points), moderate (9-12 points) and severe TBI (≤8 points). An extended version of the GCS, Glasgow Outcome Scale Extended (GOSE), was used to evaluate ability to cooperate during functional magnetic resonance imaging (fMRI). GOSE was registered three, six, and 12 months after injury.

The Head Injury Severity scale (HISS) is based on the GCS scores and defines the injury as ‘minor’ (minimal, mild, moderate) or ‘serious’ (severe and critical). In the present study, HISS was dichotomized into ‘moderate’ and ‘severe’ head injury.

Length of stay (LOS) in acute hospital was registered and dichotomized into short (<9 days) and long (≥ 9 days) LOS.

Post traumatic amnesia (PTA) was dichotomized into short (≤ 7 days) and long (> 7 days) PTA.

Diffuse axonal injury (DAI), number of contusions, and bilateral brain stem injury were identified by MRI scans within four weeks after injury. Injury type and injury velocity were also registered.

2.4.2 VLBW

Birth weight was measured on an electronic scale to the nearest gram in VLBW participants and to the nearest 10 grams in controls. Birth length and head circumference in both groups were measured to the nearest 0.1 cm.

The Apgar score evaluates the health status of the newborn on a scale from 0 to 10 based on heart rate, respiration, muscle tone, reactions, and skin color. Apgar was measured one and five minutes after birth.

CP was diagnosed by neurological examination at ages five and 14, and classified as diplegia, hemiplegia, or quadriplegia.

Full scale IQ was assessed at 20 years of age using Wechsler Adult Intelligence Scale, third edition (WAIS-III) (Wechsler, 1997).

Socioeconomic status was based on parents' education and occupation when the children were 14 years of age, and calculated in accordance to Hollingshead's Two Factor Index of Social Position (Hollingshead, 1958, Indredavik et al., 2004).

2.5 Mobility assessment – High-level Mobility Assessment Tool (HiMAT)

Advanced mobility function was assessed by the HiMAT. The HiMAT is a novel assessment tool specifically developed to examine high-level mobility function in persons with mild brain injury, and is considered valid and reliable for this population (Williams et al., 2005a, Williams et al., 2006). Due to similarities within injury characteristics and mobility outcome in adults with TBI and VLBW, and lack of alternative suitable tests for the latter group, we considered it of interest to apply the HiMAT to describe high-level mobility in the VLBW participants. The HiMAT was recently translated to Norwegian by Moen and Kleffelgård (Moen, 2011b), and the Norwegian version was used in the current study (Appendix 2).

The HiMAT consists of 13 timed mobility tasks such as walk, walk backwards, walk on toes, walk over obstacle, run, skip, hop forward, bound on both affected and non-affected leg, and negotiating stairs. For participants with no motor affection of legs, they were asked to indicate their preferred leg. If unknown, participants were asked to perform a single leg stance. The chosen leg was considered non-affected. Most items required the participant to move along a 20 meters hallway while performing the task in question. The middle 10 meters were timed, excluding the acceleration and deceleration phases in the first and last five meters. 'Walk', 'walk backwards' and 'walk on toes' were to be performed as fast as possible with one foot on the ground at all times. The 'walk on toes' task did not allow participant's heel to touch the floor. 'Walk over obstacle' involved stepping over a regular house brick. The 'skip' task involved moving by performing one hop on alternating feet forming a rhythmical pattern. 'Hop' required continuously hopping on the affected leg for the middle 10 meters of the hallway. 'Bound' was performed by standing on one leg and jumping forward landing on the other leg. 'Bound affected leg' indicates standing on the non-affected leg and landing on the affected leg. While walking up and down stairs, presence of a reciprocal pattern was registered in addition to whether or not the railing was used for support.

All items included a practice trial prior to testing. Participants were asked to complete each test item as fast as safely possible, except for bound items (as far as possible), and walking on stairs (as you would normally do). The items were scored in seconds and centimeters and transformed to item scores. Each item score varies on a scale from 0 to 4

points, except for stair tasks that are scored from 0 to 5. Furthermore, the stair items were classified as 'dependent' or 'independent' on the basis of use of railings for support. Participants walking without railings (independent) achieved the highest score on the dependent item score, in addition to a score on the independent item according to speed, while participants walking with the support of railings achieved the lowest on the independent item score, in addition to an item score on the dependent item according to their actual performance. The maximum total HiMAT score (the sum of all item scores) is 54 points, and a higher score indicates better mobility performance (Williams et al., 2005b). If a participant failed to complete a test item, the lowest possible score (0) was registered.

The HiMAT requires that the participant is able to walk 20 meters independently without gait aids (orthoses are permitted). Assessment of the test requires a stopwatch, tape measure, a brick, 20 m hallway and a staircase of 14 steps. In this study, a 12 step stair was used, and scores were therefore calculated according to the manual (measured time x 14/12). Duration of testing was approximately 10 minutes.

High-level mobility problems were defined as a total HiMAT score at or below the 5th percentile according to published sex-specific norms derived from an Australian population of healthy university students (Williams, 2009).

2.6 Procedure

All participants were asked to avoid being under the influence of any kind of caffeine, tobacco, or alcohol during testing. On the day of testing, participants were guided to a room to complete a questionnaire concerning cognitive function, psychological health, and quality of life. By random selection participants were subsequently taken to MRI, EEG and motor examinations during the day. On breaks between examinations, participants carried on with the questionnaire. They were also recommended to get some rest between examinations. MRI and EEG examinations lasted for 60 minutes each. Motor examinations lasted for 30-40 minutes and consisted of a structured interview (Appendix 1) and anthropometrical measures prior to several fine and gross motor tests. Depending on the number of participants meeting for testing that day, participants usually finished all assessments within 6 hours.

2.7 Examiners

Three examiners were responsible for motor testing and interviews, two of which were physiotherapists and one a master student in human movement science (author of this thesis).

Prior to data collection, examiners were trained by a physiotherapist with comprehensive knowledge about the HiMAT. All examiners were blinded to group adherence in the TBI study. In the VLBW study, examiners were blinded to neonatal history.

2.8 Ethics

The Regional Committee for Medical Research Ethics has approved both "Advanced MRI for diagnosis and outcome assessment in patients with traumatic brain injury (TBI)" (REK number 4.2009.1019) and "Low birth weight in a lifetime perspective" (REK number 4.2005.2605). Participants received information about participation (Appendix 3) in the study prior to examination, and written and oral informed consent was obtained from all participants on the day of testing (Appendix 4). Participants were informed that they could refuse any test item they considered unsafe or too difficult. All methods were non-invasive, and considered safe, and the mobility test was easy to use in clinical settings. Participants received 1000 NOK for participation.

2.9 Data and statistical analysis

Predictive Analytic SoftWare (PASW) Statistics for Windows, version 19.0 (SPSS Inc., Chicago, IL), was used for statistical analysis in this study. P-values less than 0.05 were considered statistically significant.

To compare proportions between groups, the chi-square test or the Fisher Exact test (when minimum expected count was less than 5) were used. The Kolmogorov-Smirnov test was used for the assessment of normality. For normally distributed data, group comparisons were performed by the Kolmogorov-Smirnov Z test (reported by Z-value). The Mann-Whitney U test (reported by U-value) is the non-parametric equivalent, and was used for group comparisons on background variables that deviated significantly from a normal distribution, and on the non-parametric data of the HiMAT. The test assumes that data are ordinal, but not normally distributed, and thus applicable to the HiMAT data.

Odds ratio (OR) with 95% confidence interval (CI) was calculated to estimate the relative risk for participants with TBI or VLBW to obtain a total HiMAT score at or below the 5^{th} percentile compared to controls. Thus, the OR gives an estimated measure of the prevalence of poor high-level mobility in adults with TBI and VLBW compared to controls. In case-control studies, OR is considered valid when conditions are rare, and is therefore suitable for assessing the risk of having mobility problems in both TBI and VLBW

populations. Cut-off values for the 5th percentile were chosen in accordance to normative values published by Williams and colleagues (Williams, 2009). The values are calculated for both sexes in participants between 18 and 25 years of age, and are therefore considered appropriate for the participants in the present study.

Correlation analyses were performed to investigate possible relationships between background variables and HiMAT results. Correlations were calculated using Spearman's rho, and p-values were set to <0.05. Variables that showed significant correlations with both the independent variable (group) and dependent variables (total HiMAT score and the 5th percentile of the total HiMAT score) were subsequently included in a logistic regression analysis as potential confounders. A reduction of the OR of at least 10% was considered of significant importance.

Two TBI participants were not able to complete all test items. Thus, in accordance with the manual, they were given a score of 0 for these tasks.

All group analyses were done both with and without pain participants in the TBI group, and with and without participants with CP in the VLBW group.

3. Results

3.1 Group characteristics

3.1.1 TBI

Background characteristics for the TBI group are presented in Table 1. Chi-square tests, Kolmogorov-Smirnov Z-tests and Mann-Whitney U-tests revealed no statistical differences in anthropometric measures, except from BMI which was lower in TBI participants compared to controls (Z=1.394, p=0.041). None of the matched variables (Sex: Fisher's Exact test, p=0.746; Age: Z=0.808, p=0.530; Education: Fisher's Exact test, p=1.000) differed significantly between participants with TBI and their control group, indicating successful matching. Exclusion of two pain participants did not change the results noteworthy. TBI participants and their controls did not show any differences in variables such as exercise, recent injury, recent illness, medication, or pain. 'Number of activities' was statistically different between the TBI group and the control group (Z=1.360 p=0.049), reflecting a higher amount of activities among controls. 'Number of activities' was still significant between groups after exclusion of two pain participants.

Table 1. Age, anthropometrical measures, and general background variables in the very low birth weight (VLBW) group, traumatic brain injury (TBI) group, and the two control groups.

Age, anthropometrics	**TBI (N=22) Mean (SD)**	**Control TBI (N=24) Mean (SD)**	**VLBW (N=35) Mean (SD)**	**Control VLBW (N=24) Mean (SD)**
Age (years)	22.9 (2.0)	23.3 (1.8)	22.5 (0.7)	22.8 (0.5)
Height (cm)	179.3 (8.5)	178.9 (8.4)	169.0 (9.5)	170.5 (9.6)
Weight (kg)	76.6 (13.9)	81.7 (13.2)	67.1 (13.9)	69.0 (14.8)
Body mass index (kg/m^2)	23.8 (2.9)	25.5 (3.3)	23.4 (4.2)	23.6 (3.8)
Head circumference (cm)	57.8 (1.9)	58.3 (1.5)	55.9 (1.9)	56.8 (1.5)
Background variables				
Exercise (number of activities)	1.7 (1.1)	2.5 (1.5)	1.7 (1.1)	2.3 (1.4)
Pain (Visual analogue scale, cm)	0.7 (1.5)	0.7 (1.9)	1.0 (2.5)	1.2 (2.4)
Background variables (yes/no)	**TBI (N=22) Number**	**Control TBI (N=24) Number**	**VLBW (N=35) Number**	**Control VLBW (N=24) Number**
Education completed (≥12yrs/<12yrs)	11/11	13/11	20/13[a]	21/3
Exercise (yes/no)	18/4	21/3	26/9	20/4
Recent injury (yes/no)	7/15	6/15[b]	10/25	8/18
Recent illness (yes/no)	0/22	2/22	9/26	8/16
On medication (yes/no)	4/18	4/19[c]	8/26[d]	8/16

SD = Standard deviation. [a] n=33, [b] n=21, [c] n=23, [d] n=34.

Group-specific variables for the TBI group are shown in Table 2. Traffic accidents was the most common injury mechanism occurring in 13 of 24 participants (59.1%). Other injury mechanisms in this group were falls in five participants (22.7%), one ski accident (4.5%), and 'unknown' in three participants (13.6%). All traffic accidents were defined as 'high velocity injuries', whereas fall, ski, and unknown accidents were defined as 'low velocity injuries'. Of the participants recovering from traffic accidents, nine stayed in hospital for nine days or more while the remaining 13 were discharged before nine days.

Table 2. Group-specific variables for the traumatic brain injury (TBI) group.

Group-specific variables	**TBI (N=22) Mean (SD)**
GOSE 3 months after injury	6.2 (1.5)[a]
GOSE 6 months after injury	7.0 (1.3)
GOSE 12 months after injury	7.2 (1.0)
	TBI (N=22) Number
Contusions (none/one/two or more)	8/3/10[b]
GOSE 12 months after injury (moderate disability/good recovery)	5/17
Glasgow coma scale (mild-moderate/severe TBI)	10/12
Head injury severity scale (moderate/severe)	10/12
Length of stay (short/long)	13/9
Post traumatic amnesia (short/long)	14/7[b]
Diffuse axonal injury (yes/no)	17/4[b]
Diffuse axonal injury in brainstem (yes/no)	2/19[b]
Injury velocity (high/low)	13/9

SD = Standard deviation. GOSE = Glasgow outcome scale extended. [a] n=14, [b] n=21.

According to the Glasgow Coma Scale (GCS), 10 participants (45.5%) had mild to moderate TBI while 12 (54.5%) suffered from severe TBI. A total of 17 TBI participants (77.3%) were diagnosed with DAI, of these two (9.1%) had DAI in the brainstem. Only one participant had bilateral brainstem injury, whereas one had missing information on this variable. Among the TBI participants, three (13.6%) had experienced one contusion, and 10 (45.5%) reported two or more. Eight TBI participants (36.4%) did not report any contusions. GOSE at three, six, and 12 months after injury showed a trend towards an increased GOSE score with increased time after injury, indicating increased recovery.

The two pain participants had good recovery according to the dichotomized GOSE 12 score, both had mild to moderate TBI based on GCS and HISS scores, and long LOS. One

had long PTA, while the other one had missing information on this variable. DAI was found in both pain participants, but did not involve the brainstem. Both suffered from a high velocity injury, but neither one reported any contusions. Exclusion of the two pain participants did not result in notable differences in GOSE three, six or 12 months post injury.

3.1.2 VLBW

Background characteristics for the VLBW group are presented in Table 1. Kolmogorov-Smirnov Z tests, Mann-Whitney U tests, and chi-square test revealed no statistical differences between the VLBW group and the VLBW control group on matched variables (sex: Fisher's Exact test, p=0.273; Age: Z=1.096, p=0.181), indicating successful matching. Statistical comparisons discovered no significant differences anthropometrical measures or background variables, such as recent injury, recent illness, pain, medication, socioeconomic status, or whether the participants exercised or not, between the VLBW group and controls. The VLBW participants were engaged in fewer activities (U=290.5, p=0.039), and a higher proportion had less than 12 years of education (Fisher's Exact test, p=0.037) compared to the VLBW controls. Exclusion of three CP participants did not change these results, except from a decrease in significance for 'number of activities' (U=277, p=0.068).

Group-specific variables are presented in Table 3. Statistical comparisons confirmed that at birth, participants born with VLBW were shorter and lighter and had smaller head circumference compared to term-born controls. Obviously, they also had significantly younger gestational age compared to the control group. Apgar scores at 1 and 5 minutes after birth were significantly poorer in VLBW participants. At 20 years of age, VLBW adults showed significantly lower IQ compared to controls. Exclusion of the three participants with CP showed similar results. Full scale IQ was significantly different between the VLBW group and the control group (Z=2.169, p=0.000). One of the three participants with CP had missing information on full scale IQ, and exclusion of the two remaining CP participants only changed the results slightly (Z=1.979, p=0.001). Days in NICU ranged from 25 to 386. In the VLBW group, 12 participants had registered information about cerebral ultrasound (CUL) findings. Eleven of these reflected normal findings, while one participant with diplegic CP had asymmetrical dilation of the ventricular system.

Table 3. Group-specific variables in participants with very low birth weight (VLBW) and controls at time of birth. Full scale IQ was measured at 20 years of age.

Group-specific variables	VLBW N = 35 Mean (SD)	VLBW excl. CP N = 32 Mean (SD)	Controls N = 24 Mean (SD)
Birth weight (grams)	1200.7 (252.8)**	1236.7 (216.1)**	3594.0 (375.6)
Birth head circumference (cm)[a]	27.0 (2.4)**	27.3 (2.3)**	35.1 (1.3)
Maternal age (years)	28.9 (5.6)	29.2 (5.5)	29.8 (4.4)
Gestational age (weeks)	29.1 (2.7)**	29.3 (2.6)**	39.4 (1.0)
Apgar 1 score[b]	6.7 (1.9)**	6.8 (1.9)**	8.8 (0.6)
Apgar 5 score[b]	8.4 (1.6)**	8.4 (1.7)**	9.9 (0.3)
NICU (days)[c]	80.8 (64.2)	75.5 (62.9)	-
Days in ventilator[c]	5.4 (13.1)	3.9 (8.6)	-
Full scale IQ[d]	85.5 (13.4)**	86.9 (12.3)*	102.8 (10.5)
Socioeconomic status[e]	3.5 (1.1)	3.4 (1.2)	4.0 (1.0)

** p<.001, * p<.05 between VLBW groups and control group. SD = Standard deviation. NICU = Neonatal intensive care unit. [a]27 VLBW / 25 VLBW [ex. CP] / 22 controls, [b] 23 controls, [c] 34 VLBW / 31 VLBW [ex. CP], [d] 31 VLBW / 28 VLBW [ex. CP] / 21 controls, [e] 22 controls

3.1.3 Control groups

Kolmogorov-Smirnov Z tests and chi-square tests revealed statistical differences between the TBI control group and the VLBW control group on anthropometrical measures and background variables. The VLBW control group had a significantly lower proportion of males (Fisher's Exact test, p=0.001), and the VLBW participants were shorter (Z=1.588, p=0.013), lighter (Z=1.876, p=0.002), and a higher proportion had 12 or more years of education (Fisher's Exact test, p=0.024), than the TBI control group. These results confirm the need for two separate control groups.

3.2 High-level mobility

3.2.1 High-level mobility in TBI

Total HiMAT score and all subscores for the TBI group and TBI controls are presented in Table 4. Mean total HiMAT score was 47.0 ± 7.7 compared to 50.3 ± 3.9 for the controls (U=193, p=0.116). Three of 13 mobility tasks differed significantly between the TBI and the control groups; 'walk', 'walk over obstacle', and 'bound non-affected leg'. When the two participants who reported pain were excluded from the analysis, mean total HiMAT score for

the TBI group changed to 48.9 ± 4.9 (U=193, p=0.264), with 'walk' and 'walk over obstacle' remaining significantly different from the control group.

Table 4. Total HiMAT score and item scores in the traumatic brain injury (TBI) group compared to controls.

HiMAT Item	TBI (N=22) Mean (SD)	Controls (N=24) Mean (SD)	U	P
Walk	**3.50 (0.6)**	**3.88 (0.3)**	**175.5**	**0.013**
Walk backwards	3.77 (0.4)	3.96 (0.2)	215	0.065
Walk on toes	3.68 (0.5)	3.88 (0.3)	213	0.117
Walk over obstacle	**3.36 (0.7)**	**3.88 (0.3)**	**160.5**	**0.005**
Run	3.00 (1.2)	3.67 (0.6)	188.5	0.057
Skip	2.86 (1.5)	3.42 (1.1)	210	0.180
Hop affected leg	3.18 (1.3)	3.79 (0.5)	195	0.055
Bound affected leg	3.32 (1.2)	3.83 (0.4)	196	0.057
Bound non-affected leg	**3.41 (1.2)**	**3.92 (0.3)**	**200**	**0.041**
Up stairs independent	3.36 (0.8)	2.96 (1.4)	235	0.477
Up stairs dependent	5.00 (0.0)	4.88 (0.3)	231	0.090
Down stairs independent	3.55 (0.7)	3.33 (1.2)	255	0.811
Down stairs dependent	5.00 (0.0)	4.92 (0.3)	242	0.171
Total HiMAT score	47.00 (7.7)	50.29 (3.9)	193	0.116

U and P values from Mann-Whitney U test. SD = Standard deviation.

In the TBI group, nine participants (40.9%) had a total HiMAT score at or below the 5th percentile compared to six participants in the control group (25%). The OR showed that TBI participants had a double risk of having high-level mobility problems, although not significant (Table 5). Both pain participants had total HiMAT scores at or below the 5th percentile. Thus, exclusion of these two pain participants reduced the OR (OR 1.6, CI 0.4 – 5.9).

Table 5. Odds ratio (OR) for having a total HiMAT score at or below the 5th percentile in the traumatic brain injury (TBI) group compared to the control group.

	≤ 5th percentile n	Crude OR (95% CI)	Adjusted OR* (95% CI)
TBI (N=22)	9	2.077 (0.6 – 7.3)	1.641 (0.4 – 6.1)
Controls (N=24)	6	1.0	

* adjusted for 'number of activities'. CI = Confidence interval.

Of the background variables, only 'number of activities' showed borderline correlation with both group (r=0.288, p=0.052) and a HiMAT score at or below the 5th percentile (r=0.273,

p=0.066). When we adjusted for this variable, the OR was reduced (Table 5). Exclusion of two pain participants did not change this result.

3.2.2 High-level mobility in VLBW

In the VLBW group, mean total HiMAT score was 45.1 ± 7.8 compared to 49.9 ± 3.5 in its control group (U=256, p=0.011) (Table 6). Five of the 13 mobility item scores were significantly different from the control group; 'walk backwards', 'run', 'hop affected leg', 'bound affected leg', and 'bound non-affected leg'. When the three participants with CP were excluded, mean total HiMAT score was to 46.8 ± 5.5 in the VLBW group, still significantly different from the control group (U=256, p=0.033). Furthermore, three mobility task scores remained significantly different from the controls; 'walk backwards', 'hop affected leg' and 'bound non-affected leg'.

Table 6. HiMAT total score and item scores in very low birth weight (VLBW) participants and controls. Participants with CP included.

HiMAT item	VLBW(N=35) Mean (SD)	Controls (N =24) Mean (SD)	U	P
Walk	3.66 (0.5)	3.67 (0.5)	416	0.939
Walk backwards	**3.49 (0.7)**	**3.92 (0.3)**	**283**	**0.007**
Walk on toes	3.51 (1.0)	3.79 (0.4)	370.5	0.324
Walk over obstacle	3.57 (0.6)	3.75 (0.4)	363	0.281
Run	**2.97 (0.9)**	**3.46 (0.6)**	**298.5**	**0.045**
Skip	2.86 (1.3)	3.38 (1.0)	321	0.098
Hop affected leg	**2.97 (1.1)**	**3.71 (0.6)**	**259.5**	**0.006**
Bound affected leg	**3.20 (0.9)**	**3.71 (0.5)**	**285**	**0.019**
Bound non-affected leg	**3.20 (0.9)**	**3.83 (0.4)**	**258**	**0.004**
Up stairs independent	2.77 (1.1)	3.25 (0.7)	312	0.078
Up stairs dependent	4.94 (0.2)	5.00 (0.0)	396	0.237
Down stairs independent	3.09 (1.3)	3.50 (1.0)	347.5	0.195
Down stairs dependent	4.91 (0.3)	4.96 (0.2)	401.5	0.512
Total HiMAT score	**45.14 (7.8)**	**49.91 (3.5)**	**256**	**0.011**

U and P values for Mann Whitney U Test. SD= Standard deviation.

When the three subjects with CP were excluded from analysis, the differences remained mainly the same, except for 'run' which was non-significant (U=297.5, p=0.122). 'Bound non-affected leg' decreased to borderline statistical significance (U=285, p=0.059).

Among VLBW participants, 17 (48.6%) had a total HiMAT score at or below the 5th percentile, compared to only 4 participants (16.7%) in the control group. The OR from the logistic regression analysis showed that participants in the VLBW group were 4.7 times more likely to have high-level mobility problems compared to the control group (Table 7). All CP participants had high-level mobility problems. Exclusion of the three participants with CP showed a decreased, but still statistically significant OR (Table 7).

Table 7. Odds ratio (OR) for having a total HiMAT score at or below the 5th percentile in the very low birth weight (VLBW) group compared to the control group.

	≤ 5th percentile (n)	**Crude OR (95% CI)**	**Adjusted OR* (95% CI)**
VLBW (N=35)	17	4.722 (1.3 – 16.7)	3.967 (1.1 – 14.6)
VLBW CP excl. (N=32)	14	3.889 (1.1 – 14.0)	3.363 (0.9 – 12.5)
Controls (N=24)	4	1.0	

***** adjusted for 'number of activities'. CI = Confidence interval. CP = Cerebral palsy.

When performing a correlation analysis, only 'number of activities' correlated with both group (r=0.271, p=0.038), total HiMAT score (r=0.285, p=0.029), and a HiMAT score at or below the 5th percentile (r=0.300, p=0.021). When we adjusted for this variable in the logistic regression analysis, the OR was reduced by 24.5%. This indicates that high-level mobility problems in the VLBW group were affected by the number of activities, but the analysis also demonstrate that significant problems still were present among participants born VLBW compared to their control group after adjusting for the variable (Table 7).

3.2.3 Comparing high-level mobility in participants with TBI and VLBW

Differences in age, anthropometric measures and background variables between participants born with VLBW and participants with TBI were investigated performing Kolmogorov-Smirnov Z tests, chi-square tests, and Mann-Whitney U tests. The VLBW participants were shorter (Z=1.484, p=0.024), and had smaller head circumference (Z=1.475, p=0.026) than the TBI participants. In addition, a higher proportion of the VLBW participants reported recent illness (Fisher's Exact test=0.009). The sex distribution between the two groups was borderline significantly different, with a higher proportion of females in the VLBW group (Fisher's Exact test=0.057). The TBI participants were slightly older than VLBW participants (Z=1.356, p=0.51). No differences were found between groups in weight, BMI, pain, recent injury, medications, exercise, number of activities, or education. These differences did not change noteworthy when TBI participants with pain and VLBW participants with CP were

excluded, except from no significant difference in age between groups, and weight showing borderline lower weight in the VLBW group (Z=1.338, p=0.056).

The Mann-Whitney U test showed no difference in total HiMAT scores between the VLBW and the TBI groups. Only one item, 'up stairs independent', differed significantly between the two groups (U=262, p=0.033), due to a lower mean subscore in the VLBW group. When participants with pain and CP were excluded, the difference was borderline significant (U=225, p=0.058). A logistic regression analysis was performed to estimate the risk for having a HiMAT score at or below the 5th percentile in the TBI group compared to the VLBW group. The result of the analysis shows that, compared to the VLBW group, TBI participants had lower risk for having high-level mobility problems (Table 8). This is consistent with the results from the separate analyses for each group, which showed a higher proportion of high-level mobility problems in the VLBW group compared to its controls, than in the TBI group compared to its controls. Exclusion of two participants with pain from the TBI group, and three participants with CP from the VLBW group did not change the results (OR 0.692, CI 0.218 – 2.196).

Table 8. Odds ratio (OR) for having a total HiMAT score at or below the 5th percentile in the traumatic brain injury (TBI) group compared to the very low birth weight (VLBW) group. CP and pain participants included.

	≤ 5th percentile n	**Crude OR (95% CI)**
TBI (N=22)	9	0.733 (0.249 – 2.154)
VLBW (N=35)	17	1.0

CI = Confidence interval.

A correlation analysis showed that the variables 'height' and 'head circumference' correlated with both group and total HiMAT score, with r's varying between -.435 and -.481, and p's varying between 0.000 and 0.002. None of the correlating variables reduced the crude OR.

4. Discussion

In this study, we found that both adults suffering from TBI and adults born with VLBW had reduced high-level mobility compared to controls. Furthermore, the two groups showed problems in different high-level mobility tasks. These were 'walk backwards', 'run', 'hop affected leg', 'bound affected leg', 'bound non-affected leg', and 'total HiMAT score' in the VLBW group, and 'walk', 'walk over obstacle' and 'bound non-affected leg' in the TBI group. High-level mobility problems persisted when excluding TBI participants reporting pain and VLBW participants with CP from the analyses. The TBI participants had a lower, but non-significant, risk for having high-level mobility problems compared to adults born with VLBW. Logistic regression analyses indicated that TBI participants had a double risk for having high-level mobility problems compared to controls, although this finding was not significant. In the VLBW group, the risk was fourfold after adjustment for possible confounding by number of activities, and statistically significant compared to controls.

In the following sections, methodological considerations will be discussed first to outline methodological strengths and limitations for the present study. Subsequently, consistency of the current findings with earlier investigations will be discussed, and finally, aspects of high-level mobility in adults with TBI or VLBW will be addressed and discussed, followed by conclusions and suggestions for further research.

4.1 Methodological considerations

HiMAT - standardization

The HiMAT is specifically developed, and considered valid, for a TBI population. Furthermore, the normative cut-off values used in the present study are in accordance with the HiMAT manual (Williams, 2009). They are calculated for both sexes between 18 and 25 years of age, thus considered suitable for the age span in the present study. However, the cut-off values are based on university students from physiotherapy and rehabilitation and occupational therapy studies (Williams, 2009), which may involve students whose lifestyle is more active and healthier than the general population, from which our control groups were drawn. Furthermore, higher education is associated with higher physical activity levels (Pan et al., 2009, Smith et al., 2009). Combined, these conditions may have resulted in cut-off values too strict for the general population. In our TBI control group, as much as 25% of the participants had a total HiMAT score at or below the 5^{th} percentile, and 17% in the VLBW control group, compared to the expected 5%. This indicates that our control groups had poorer

high-level mobility compared to the sample used to construct the cut-off values, which may have undermined the group comparisons. In addition, our TBI group showed better HiMAT scores than the TBI group in the original study, making it more difficult to find group differences.

In both participants with TBI or VLBW, cognitive impairments can be present. Unfortunately, it was not possible to investigate the degree of cognitive impairment in the TBI group in this study. However, as a GOSE score below five was an exclusion criterion in the larger study, this should imply that TBI participants with the most impaired cognitive outcome were excluded. We did find that the VLBW participants had lower IQ than their controls. Nonetheless, the HiMAT is considered not discriminative regarding cognitive abilities (Williams et al., 2005b), and thus cognitive impairments are not expected to have affected the results.

Separate control groups

The controls in this study were recruited from two larger studies. There are several reasons for using two separate control groups in the present study rather than a single group functioning as control group for both the TBI and VLBW groups. Firstly, the controls in the larger studies were recruited based on different matching criteria, namely age, sex, and education in the TBI control group, and age and sex in the VLBW control group. In addition, both control groups were recruited from the same geographical area as the case groups. Furthermore, the original VLBW controls were recruited over 20 years ago, when their pregnant mothers enrolled in the study on causes and consequences of intrauterine growth restriction. Statistical comparisons indicated that the two control groups were significantly different from each other with respect to sex distribution, height, weight, and education, and therefore considered not suitable to be treated as a single control group.

Robustness of findings

There is always a possibility that research results can occur by chance. The p-value indicates the probability of obtaining an observed difference in a study sample, if the null-hypothesis is true. The p-values in this study were set to be below 0.05. Given this criterion, only three subscores were significantly different between TBI participants and TBI controls, with p-values ranging from 0.005 to 0.041. However, the likelihood of obtaining significant results increases with sample size. Some of the subscores showed borderline significance, which may

indicate true differences between TBI participants and controls, given the small sample size. Thus, it is important to consider the non-significant findings with caution. Nevertheless, the observed differences between the VLBW group and controls were supported by overall highly significant p-values, therefore indicating robust findings.

To ensure high validity of a study, the selection of participants is important. Even though the participants in this study were originally recruited in the two larger studies, it is important to have in mind that participants not willing to participate in the follow-up might have had reasons related to e.g. mobility, which might lead to selection bias. Participation primarily for economic reasons might also be an aspect of selection bias, as remuneration was given to every participant in the study. If selection biases are present in this study, they will most likely have been in the direction of better mobility function, which in turn could have led to an underestimation of high-level mobility problems in our study groups.

The recruitment of TBI controls among TBI cases' families and social networks can be a threat to the internal validity of a study. According to Grimes and Schultz (2005), cases tend to introduce controls with similar education and socioeconomic status. Furthermore, Kaplan et al. (1998) found that controls recruited from cases' friends often were somewhat more "acceptable" (e.g. more educated) than the cases themselves, which might introduce overmatching. However, the controls were matched on education, and thus biases related to the recruitment of controls are not likely to have occurred.

All three examiners were blinded to group assignment in the TBI group, but not in the VLBW group. However, the examiners were blinded to results of previous examinations in the VLBW and its control group, and this should reduce the risk of information bias.

According to the HiMAT manual, a 14-step staircase is required. In the current study, a 12-step staircase was used due to not having a 14-step staircase available, and thus the score for the stair tasks had to be estimated from a shorter staircase. However, all participants in both case and control groups underwent this procedure, and this should therefore not constitute any bias between the groups.

Confounding factors

Confounding occurs when variables other than those examined affect the outcome variable, and thus contribute to reduced internal validity of a study. In this study, we used three different strategies in order to control for possible confounding factors; matching, logistic regression analysis, and partial exclusions.

Controls were matched on age, sex, and geographical area, thus, these variables should not be confounding factors. Furthermore, age ranged from 20 to 25 years in all groups. This is a relatively narrow range, and age-related differences regarding mobility outcome within this range are unlikely, further supporting that age is unlikely to be a confounding factor.

Even though TBI and VLBW participants were matched by sex, sex distribution differed between TBI and VLBW groups. This may have influenced the comparison on the raw scores, but should not affect the OR, since the normative cut-off values are sex-specific.

TBI cases and controls were also matched on educational level, reducing the risk of education as a confounder for physical activity levels, as higher educational levels are associated with higher levels of physical activity. In the VLBW group, socioeconomic status could be a corresponding potential confounder for physical activity level. However, socioeconomic status did not differ significantly between VLBW participants and controls, and the confounding effect should therefore be minimal.

Of the different background variables, only 'number of activities' was identified as a potential confounder, and subsequently included in the logistic regression analysis. It may be difficult to determine whether participation in several activities is a result of having better high-level mobility, or whether having better high-level mobility is a result of engagement in multiple activities. However, the risk of having mobility problems in the TBI and VLBW group compared with controls remained after adjusting for this variable, although only significant between VLBW participants and controls. In the comparison between the TBI and the VLBW group, 'height' and 'head circumference' were identified as potential confounders, but did not affect the OR.

Because of the high prevalence of motor problems associated with CP, it could be expected that the three participants with CP in the present study contributed disproportionately to the high-level mobility problems in the VLBW group. However, when excluding the participants with CP from the statistical analyses, the VLBW group still showed increased risk of having high-level mobility problems. Thus, the presence of participants with CP could not explain the association between very low birth weight and poor HiMAT scores. Furthermore, there is debate whether CP should be considered as a confounding factor, or as one of factors in the causal chain between low birth weight and functional outcome.

4.2 High-level mobility outcome in adults with TBI

In participants with TBI, 'walk', 'walk over obstacle' and 'bound non-affected leg' were significantly different from TBI controls. Surprisingly, the TBI participants demonstrated more difficulties walking as fast as they could, while in some of the seemingly more complex task, they did not perform worse than controls. As an example, walking and running are mobility tasks showing similarities regarding movement pattern, but running involves higher requirements regarding strength and balance (Shumway-Cook and Wollacot, 2012). However, earlier investigations are consistent with the current findings. In patients with extremely severe TBI, Williams and colleagues (2009) reported reduced self-selected walking speed mainly due to shorter stride length, which in turn was due to reduced cadence. McFadyen et al. (2003) reported similar findings in eight high-functioning TBI adults in unobstructed and obstructed walking, and attributed the reduced walking speed to shorter stride length and general instability, rather than reduced cadence. The latter interpretation is supported by Chou et al. (2004), who also attributed the reduced walking speed to shorter stride length. Furthermore, Williams et al. (2009) found that the TBI patients with slow walking speed had reduced push-off, or a stiff-legged gait pattern, and considered this a more likely explanation for the reduced gait speed. Although the TBI population in Williams' study had on average a more severe injury than our participants, it is likely that walking speed is affected by the same variables, although perhaps to a lesser extent with less severe injury. However, none of these studies used the HiMAT to measure walking speed, and therefore, comparisons with these studies might be limited on this variable.

The TBI group also scored significantly lower in the 'walk over obstacle' task. The abovementioned study by McFadyen and colleagues (2003) reported reduced walking speed among the TBI patients when compared to healthy controls in obstructed as well as unobstructed walking. As the subjects were asked to walk at their natural speed, McFadyen's study is not comparable to our study regarding walking speed, but the decrease in walking speed in tasks requiring negotiating an obstacle is in accordance with the poor performance in our study. Furthermore, McCulloch et al. (2010) used the HiMAT in their study on balance and dual-task performance, and the associations with falls after the onset of injury, in 24 subjects (mean age 39.4 years) with acquired brain injury. They reported motor slowing in dual tasks, and suggested this was due to an adaptive strategy for safe accomplishment of the tasks (McCulloch et al., 2010). In our study, a similar strategy might be reflected in the poor

performance in the ‘walk over obstacle’ tasks, as the task involves requirements of both walking and negotiation of an obstacle.

The ‘bound non-affected leg’ task suggests that TBI participants have more difficulties standing on the affected leg and landing on the non-affected leg than the other way around, standing on the non-affected leg and landing on the affected leg. The lower score compared to controls in this task can be caused by reduced strength and balance in the affected leg. The ‘bound affected leg’ task, which was not significantly different from controls, requires the participant to land on the affected leg. The expectancy was that landing on the affected leg should involve higher requirements for strength and balance, and also be influenced by cautiousness, than landing on the non-affected leg. However, this does not seem to be the case with performance being poorer when starting on the affected leg. Poor balance (Sosnoff et al., 2008, Hillier et al., 1997) and poor postural control (Sosnoff et al., 2008) are well-known impairments in persons suffering from TBI and presumably important factors regarding the bounding tasks, as the latter requires the ability to balance one’s body weight on one limb, which is particularly challenging when that side of the body is affected by an injury. The study by McCulloch et al. (2010) also found a trend that subjects reporting no falls obtained higher HiMAT scores than fallers, suggesting that fallers may have had more impaired balance.

In addition, poor planning might also be an aspect underlying the findings, as the obstructed task requires some degree of planning to be completed successfully. The frontal lobe administers planning, execution and evaluation of motor output, (Kolb and Whishaw, 2001), and focal injury to this area might induce impairments related to the planning (Brodal, 2007) of passing an object during walking. McFadyen et al. (2003) also mention the possibility that reduced obstructed walking speed in their group of TBI participants was caused by caution. A review by van Reekum et al. (2005) supports this suggestion, giving compelling evidence for anxiety disorders after mild TBI.

One might also consider the possibility that the obstacle negotiation itself is not the problem. The task requires the participant to walk as fast as he or she can, and because the TBI participants show reduced walking speed in the ‘walking’ task, it is possible that the poor performance in the ‘walk over obstacle’ task was primarily due to reduced walking speed. Unfortunately, the HiMAT only measures each task as a whole, and does not define during which part of the task the participants slow down their walking speed. Further studies could combine HiMAT measurements with motion capture, thereby allowing separation of walking speed during different parts of the task.

In the larger TBI study, from which the present sample is selected, Moen (2011a) reported the HiMAT results for 69 TBI participants, aged 16 to 65 years. Moen found significantly lower total HiMAT scores in persons with TBI compared to controls. Furthermore, 51 of 69 TBI participants (76.1%) had a score at or below the 5th percentile, compared to 32 of 76 controls (43.8%) controls. Of the 13 HiMAT sub items, Moen reported significant differences between TBI participants and controls in as much as ten sub items (only 'up stairs dependent/independent', and 'down stairs dependent' were non-significant). The higher proportion of significant subscores in the larger study compared to the present study might be due to Moen's larger sample and the higher proportion of female participants. While it is unclear whether sex affects mobility outcome after TBI (Slewa-Younan et al., 2008a, Slewa-Younan et al., 2004, Slewa-Younan et al., 2008b), healthy women do have poorer HiMAT scores (Williams, 2009) and thus, a higher proportion of female participants are likely to result in overall poorer HiMAT scores.

Motor outcome and recovery from TBI depend on the severity of the injury. Although the majority of the TBI participants in this study were diagnosed with DAI, two thirds had short PTA, and nearly half of the participants were characterized with mild to moderate TBI. Additionally, the majority showed good recovery 12 months after injury measured with GOSE. An overall low injury severity, combined with good recovery, might have contributed to the limited significant differences in high-level mobility in the TBI group compared to its control group.

In their studies using HiMAT to assess high-level mobility in TBI patients (Williams et al., 2009, Williams et al., 2010, Williams et al., 2006, Williams et al., 2005b), Williams and his colleagues have used populations that are quite different from ours. The majority of the TBI participants in these studies suffered from extremely severe TBI, and in one of the studies nearly half of their patients had also sustained at least one leg fracture (Williams et al., 2005b). The severity of TBI in these patients was determined by length of PTA, which varied from 21.5 to 71.75 days. In contrast, the persons in our TBI group had less severe TBI and 14 out of 21 participants had less than 7 days of PTA. Due to the substantial differences in injury severity, our results cannot be directly compared to the results from Williams et al.'s studies.

Because of the exclusion of TBI participants with a GOSE score below five in the larger TBI study, we have probably excluded the TBI participants with the worst mobility outcome, meaning that the TBI group in our study was characterized by overall good recovery. Another aspect that is likely to have influenced the reduced differences in mobility

between TBI participants and controls in the current study is that our control group had poorer high-level mobility outcomes than the controls used to construct the cut-off values.

4.3 High-level mobility outcome in adults with VLBW

In the VLBW group, the results demonstrate difficulties in a substantial range of the HiMAT tasks. 'Walk backwards', 'run', 'hop affected leg', 'bound affected leg', and 'bound non-affected leg' were significantly different from controls. Combined, these tasks lead to a significantly reduced total HiMAT score in the VLBW group compared to their controls.

As participants cannot see in the direction they are speeding in the 'walk backwards' task, it might be affected negatively by anxiety and uncertainty in the VLBW group. In fact, Indredavik et al. (2004), have reported higher prevalence of anxiety in this VLBW population compared to controls.

The VLBW group also had significantly lower scores in 'bound affected leg', 'bound non-affected leg' and 'hop affected leg'. 'Hop affected leg' and 'bound non-affected leg' both required starting in a standing position on the affected/non-dominant leg, and it is likely that balance-related problems increase when the task requires balancing on the poorest leg. The affected/non-dominant leg is likely to have reduced strength, balance and stability. On the other hand, significant difficulties were also apparent in the 'bound non-affected leg' task, suggesting that e.g. balance impairments also are likely to affect mobility tasks performed on the better leg, or in this case the dominant leg. Impaired balance characteristics in VLBW children and adolescents are well-known, and supported by several studies (Evensen, 2010, de Kieviet et al., 2009). The cerebellum is the main area for control of locomotion and whole-body posture (Coffman et al., 2011), and is not fully developed until the last months of pregnancy (Volpe, 2009b). Being born before the 37^{th} week of gestation with concomitant decreased cerebral volume may therefore have contributed to the poor balance seen in VLBW group.

Bound is described as a strong predictor for running (Williams and Goldie, 2001) and might reflect the difficulties also seen in the 'run' task. Studies using the Bruiniks-Oseretsky Test of Motor Proficiency (BOTMP) have also reported poor running performance in VLBW children (Wocadlo and Rieger, 2008) and children born with extremely low birth weight (birth weight $\leq$ 800 grams) (Holsti et al., 2002). Unfortunately, these studies only reported reduced gross motor performance based on the total BOTMP score, and not performance on the running task in particular.

After the exclusion of participants with CP, the 'run' task was no longer significantly different and 'bound non-affected leg' only borderline significantly different from controls. Although participants with CP did not explain the risk of having mobility problems in the VLBW group, these findings indicate that reduced running speed and problems with hopping onto the non-affected/dominant leg are difficulties primarily associated with CP.

The current study is the first to use the HiMAT in VLBW participants. As a consequence, caution must be carried out when interpreting the results. Nearly half of the VLBW participants had a total HiMAT score at or below the 5th percentile when using the cut-off values of Williams et al (Williams, 2009). By way of comparison, only four of 24 VLBW controls obtained similar low total HiMAT scores. Thus, the HiMAT is sensitive enough to detect high-level mobility problems in young adults born with VLBW. Results from the current study should encourage further development of the HiMAT for specific use in VLBW populations, including formal tests of validity and reliability.

Although no other study has used the HiMAT in adults with VLBW, our findings of mobility problems in adults born with VLBW are consistent with existing literature based on younger populations. Although previous studies have used other outcome measures, e.g. Movement ABC and BOTMP, they have likewise shown that motor problems in VLBW are persistent into adolescence (Evensen et al., 2004). The findings of our study further indicate that problems with advanced mobility persist into early adulthood as well.

Consequently, this highlights the importance of further research on high-level mobility in adulthood, using comparable mobility outcome measures. Furthermore, the evidently reduced motor and mobility outcomes from early infancy to early adulthood in persons born with VLBW indicate that brain injuries occurring at early stages of life persist into older ages.

4.4 Comparing adults with TBI and adults with VLBW

Although there are obvious limitations when wishing to directly compare the HiMAT results in the TBI and the VLBW group, it is still of valuable interest with respect to understanding long-term high-level mobility outcome in these two groups. The results of this study suggest that both adults with TBI or VLBW have mobility problems, and that 'number of activities' may play an important role for the presence of high-level mobility problems in both groups. The main difference in the results between the TBI group compared to controls, and the VLBW group compared to controls, was that the two groups demonstrated problems in different high-level mobility items. However, it is worth noting that many of the items that

were significantly different between the VLBW group and their controls, namely ‘run’, ‘hop affected leg’, and ‘bound affected leg’, showed borderline significance in the TBI group as well. Given that the TBI group in the current study had relatively mild TBI, this might indicate that high-level mobility problems in TBI and VLBW participants are rather similar, although in the current study only significant in the VLBW group. The non-significant differences between TBI participants and controls could further be due to the small sample size, or to the relatively poor high-level mobility performance in the control group.

Most stair tasks were non-significant in both groups. As the participants were asked to walk the stairs as they normally would, examiners observed a wide variety of strategies to complete the task during testing. While some participants walked the stairs at a leisurely pace, others ran the stairs two by two. In addition, because of ethical reasons related to safety, the test does not require the participants to walk the stairs as fast as they can. From the current results, it is difficult to determine whether TBI and VLBW participants did not have difficulties walking on stairs, or whether the stair tasks were not sensitive enough to detect difficulties in the participants. This raises the question as to what extent the stair tasks with the current instructions are suitable to investigate high-level mobility.

Tasks such as ‘walking backwards’ and ‘hop affected leg’ are likely to represent activities that are seldomly practiced in the majority of a healthy population, and probably even more seldomly in a VLBW or a TBI population. According to Johnston (2009), improvement in motor function depends on an increment of the frequency and strength at which synapses are being used. If a certain motor skill depends on repetition and practice of the actual skill, this may explain some of the poor HiMAT scores in the case groups. In addition, low participation in leisure time physical activities are reported in both VLBW (Kaseva et al., 2012) and TBI (Wise et al., 2010) populations, further reducing the amount of experience with high level mobility tasks.

In both groups, difficulties in several tasks seem to be associated to balance. In addition, strength might also be an important aspect related to the ability to accelerate and maintain speed, although reduced muscular strength is a less commonly reported impairment in both groups. The only task in which both case groups performed significantly worse than control groups was the ‘bound non-affected leg’ task. As this task involves balancing on the participant’s most affected leg, and requires strength to jump as long as possible before landing, it introduces high demands to both balance and strength. Although this was the only task that presented significant problems for both case groups, many of the other HiMAT tasks seem to require a certain level of both balance and strength as well. As balance is crucial for

successful mobility (Frank and Patla, 2003) and the most prevailing gross motor impairment in both groups, it is likely that poor balance is an important factor for many of the significantly lower scores. Furthermore, all tasks are timed and therefore related to speed, which is another reported impairment in both TBI and VLBW participants (de Kieviet et al., 2009, Chou et al., 2004).

Somewhat unexpected, there were no strong indications that adults with TBI or VLBW experienced increasing mobility problems as the complexity of the mobility task increased, particularly not in TBI participants. This might suggest that both TBI and VLBW participants have difficulties performing specific motor tasks, rather than that the motor problems increase as the complexity of the task increases.

A significantly reduced total HiMAT score and a higher amount of significant items in the VLBW group suggests an overall reduced high-level mobility in this group, while in the TBI group, the problems may seem more specific. In TBI, one of the most commonly affected injury site is the corpus callosum (Arfanakis et al., 2002), while brain injury caused by being born with VLBW is often more widespread and located in several cites of the brain, among them the corpus callosum (Skranes et al., 2005). The corpus callosum is the area in which the two hemispheres communicate (Brodal, 2007), and injury in this region is found to be associated with poorer gait in elderly (Srikanth et al., 2010). Thus, the reduced walking speed detected in some of the HiMAT tasks in this study might reflect the effect of the corpus callosum being a common injury site in both TBI and VLBW populations.

In addition, both PVL and DAI are characterized by white matter damage and reduced connectivity. The prevalence of problems in tasks related to e.g. speed is reflected by alterations in connectivity, and thereby a possible contribution to the reduced speed in many of the HiMAT tasks investigated in this study.

On basis of the current study, we cannot say that either TBI or VLBW participants had the better high-level mobility outcome. There were no significant differences in total HiMAT score between TBI and VLBW participants, nor did the TBI group had significantly lower risk of having high-level mobility problems compared with the VLBW group. Thus, even though our results may suggest better advanced mobility outcomes after TBI, in terms of fewer significant findings compared to its control group, caution must be made regarding non-significant findings due to the small sample size. There might also be additional background- and group-specific variables not examined in this study, that may be important factors regarding the understanding of high-level mobility in the two groups. Furthermore, the merging of two separate studies, in which participants were selected by different criteria and

matching variables, require caution when comparing across case groups. Most importantly, one should keep in mind that, despite many similarities regarding injury type and outcome, there are very different mechanisms that caused the injuries.

In conclusion, persons with TBI and VLBW show similar problems related to high-level mobility. Furthermore, the difficulties related to mobility persist into early adulthood in the VLBW group and, to a lesser extent, also in adults suffering from TBI. This demonstrates the importance of clinical support and attention regarding evaluation and rehabilitation of common difficulties with advanced mobility in these populations. Finally, the results of this study motivate further investigation of high-level mobility in adult VLBW and TBI populations.

4.5 Clinical implications

The results of this study may contribute to increasing the understanding among health workers regarding advanced mobility problems in both adults with TBI and adults born with VLBW. Young adults increasingly experience academic and work-related demands and consequently, the HiMAT may be used to determine whether persons with TBI or VLBW have the required high-level mobility skills for returning to work, sports and social activities. Furthermore, the HiMAT can be used to provide goals for rehabilitation to achieve pre-injury mobility level in TBI patients.

If further studies likewise indicate that the HiMAT indeed can be used in adults born with VLBW, the current study will be an important contribution in expanding the knowledge of mobility problems in this growing population.

Mobility problems related to balance seem to be a general problem in both TBI and VLBW participants. This highlights the importance of early detection of balance impairments in children with VLBW, and also early implementation of rehabilitation after TBI. Retraining and rehabilitation in both VLBW and TBI populations should focus on balance in relation to attainment of mobility skills beyond walking.

5. Implications for future research

Firstly, as Williams (2004) suggests that the HiMAT might be a suitable tool for other neurological conditions than TBI in young adults, this study should inspire the formal investigation of the applicability of the HiMAT in VLBW populations. This would entail further development and testing of appropriate cut-off values, and preferably, also for populations beyond the currently validated age range. Secondly, because this study is the first of its kind to demonstrate that high-level mobility problems in both VLBW and TBI populations persist into young adulthood, future investigations of high-level mobility problems in further adulthood in these populations should be implemented. Finally, the design of the current study is not appropriate for identifying cause and effect relationships, but the findings may stimulate further investigations regarding etiology of high-level mobility in TBI and VLBW populations.

6. Conclusion

Our study is one of few to report high-level mobility problems assessed by the HiMAT in adults with TBI, and the first to apply the HiMAT in a VLBW population. It is also the first study to compare high-level mobility problems in these two groups of possible brain injury.

The current study found that significant high-level mobility problems were present in adults with TBI, although the total HiMAT score was not significantly different from the control group. In addition, adults with TBI had a twofold risk of having high-level mobility problems compared to controls. When adjusted for number of activities the risk estimate was somewhat reduced, but still higher in the TBI group compared to controls.

The VLBW group had significantly reduced high-level mobility problems compared to controls, and was found to have an estimated risk for high-level mobility problems more than four times that for controls. Adjusted for number of activities, the risk was still fourfold for the VLBW group compared to controls.

When the TBI group was compared directly to the VLBW group, adults suffering from TBI had reduced risk of high-level mobility problems, although not significantly. Strength and balance in particular seem to be important factors for high-level mobility problems in both groups.

Our study shows that there is a wealth of information to be gained when investigating mobility beyond straightforward, level and unobstructed walking, e.g. jumping, hopping, bounding, and backwards walking. Our study also indicates that there exist high-level mobility problems in adult TBI and VLBW populations. Combined, these results motivate to further investigate advanced mobility in both these and other populations at risk of mobility problems.

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Appendix 1

Generelt skjema	Dato:
	Id. nr:

Navn: _____

Fødselsdato: _____

Høyde: _____ **Vekt:** _____ **Hodeomkrets:** _____

Trener du? **JA** **NEI**

Evt. hva? _____

Hvor ofte? (pr. uke) _____

Hvor lenge? (pr. gang) _____

Har du alltid trent like mye/lite?

_____

Er du/har du vært syk i det siste som du tror vil påvirke din fysiske prestasjon:

_____

Evt. medikamenter: _____

Har du skader i det siste som du tror vil påvirke din fysiske prestasjon:

Hvor: _____

Skadetidspunkt: _____

Smerter (VAS):

0 _____ 10

Appendix 2

HiMAT: HIGH-LEVEL MOBILITY ASSESSMENT TOOL

DATO.....
ULYKKESDATO.....
DIAGNOSE.....
AFFISERT SIDE VENSTRE/HØYRE

PASIENT ID

			SKÅR				
DELTEST	RESULTAT	0	1	2	3	4	5
GÅ	sek	X	> 6.6	5.4–6.6	4.3–5.3	< 4.3	X
GÅ BAKLENGS	sek		> 13.3	8.1–13.3	5.8–8.0	< 5.8	X
GÅ PÅ TÅ	sek		> 8.9	7.0–8.9	5.4–6.9	< 5.4	X
GÅ OVER HINDRING	sek		> 7.1	5.4–7.1	4.5–5.3	< 4.5	X
LØPE	sek		> 2.7	2.0–2.7	1.7–1.9	< 1.7	X
HINKEHOPP*	sek		> 4.0	3.5–4.0	3.0–3.4	< 3.0	X
HINKE (mest affisert ben)	sek		> 7.0	5.3–7.0	4.1–5.2	< 4.1	X
SPRANG** (mest affisert ben)	1) cm 2) 3)		< 80	80–103	104–132	> 132	X
SPRANG** (minst affisert ben)	1) cm 2) 3)		< 82	82–105	106–129	> 129	X
OPP TRAPP IKKE SELVSTENDIG (bruk av rekkverk **ELLER** ikke-resiprokt mønster***: hvis ikke skår 5 her og grader nedenfor)	sek		> 22.8	14.6–22.8	12.3–14.5	< 12.3	
OPP TRAPP SELVSTENDIG (uten rekkverk **OG** resiprokt mønster***: hvis ikke skår 0 her og grader ovenfor)	sek		> 9.1	7.6–9.1	6.8–7.5	< 6.8	X
NED TRAPP IKKE SELVSTENDIG (rekkverk **ELLER** ikke-resiprokt mønster***: hvis ikke skår 5 her og grader nedenfor)	sek		> 24.3	17.6–24.3	12.8–17.5	< 12.8	
NED TRAPP SELVSTENDIG (uten rekkverk **OG** resiprokt mønster***: hvis ikke skår 0 her og grader ovenfor)	sek		> 8.4	6.6–8.4	5.8–6.5	< 5.8	X
	DELSUM						

* Hinkehopp er å bevege seg fremover med et lite hink etter hvert steg/sprang.
** Et sprang er et hopp fra det ene benet til det andre med en svevefase.
*** Resiprokt mønster er å plassere en fot på hvert trinn vekselvis.

TOTAL HiMAT-SKÅR /54

Instruksjoner

Egnethet: HiMAT egner seg til å vurdere balanse- og bevegelses problemer hos mennesker med et høyt funksjonsnivå. Minstekravet for testing er 20m selvstendig gangfunksjon uten ganghjelpemidler. Ortoser er tillatt.

Testing: Testingen tar 5–10 minutter. Pasientene tillates et prøveforsøk før hver deltest.

Instruksjoner:
Pasientene blir bedt om å utføre deltestene så raskt som mulig, men i en hastighet som ikke går utover sikkerheten. Deltestene sprang- og trappegange er unntatt fra dette, se instruksjonsmanual.

Gå: Tiden pasientene bruker på de midterste 10m av 20m registreres (fra 5 til 15 m).

Gå bakover: Som for "gå".

Gå på tå: Som for "gå". Hvis hælen kommer i kontakt med bakken er deltesten ikke godkjent.

Gå over hindring:
Som for "gå". En murstein plasseres på tvers midtveis i gangbanen (ved 10 m). Pasientene må gå over mursteinen uten å komme i kontakt med den. Deltesten er ikke godkjent hvis pasientene går rundt mursteinen eller kommer i kontakt med den.

Løpe: Tiden pasientene bruker på de midterste 10m av 20m registreres. Deltesten er ikke godkjent hvis pasientene ikke har sammenhengende svevefaser, ingen dobbel standfase gjennom hele deltesten.

Hinkehopp: Hinkehopp er å bevege seg fremover med et lite hink/etter hvert steg/sprang.
Tiden pasientene bruker på de midterste 10m av 20m registreres. Deltesten er ikke godkjent hvis pasientene ikke har sammenhengende svevefaser, ingen dobbel standfase gjennom hele deltesten.

Hinke: Pasientene står på mest affisert ben og hinker fremover. Tiden pasientene bruker på å hinke 10m registreres.

Sprang (mest affisert):
Et sprang er et hopp fra det ene benet til det andre med en svevefase. Pasientene står bak en strek på minst affisert ben, hendene på hoftene. Pasientene hopper fremover og **lander på mest affisert ben**. Hvert sprang måles (i cm) fra startstreken til hælen på benet pasientene lander på. Gjennomsnittet av tre forsøk registreres.

Sprang (minst affisert):
Pasientene står bak en strek på mest affisert ben, hendene på hoftene. Pasientene hopper fremover og **lander på minst affisert ben**. Gjennomsnittet av tre forsøk registreres.

Opp trapp: Pasientene blir bedt om å gå opp en trapp med 14 trinn på samme måte som de vanligvis gjør i normalt gangtempo. Tiden fra pasientene starter til de står med begge benene på toppen av trappen registreres. For pasienter som bruker rekkverk og/eller et ikke-resiprokt mønster*, registreres resultatet i deltesten **Opp trapper ikke selvstendig**. For pasienter som går opp trappene med resiprokt mønster* uten rekkverk, registreres resultatet i

deltesten **Opp trapper selvstendig**, og de får 5 tilleggspoeng i den siste kolonnen i Opp trapper ikke selvstendig.

*Resiprokt mønster: plassere en fot på hvert trinn vekselvis.

Ned trapp: Som for Opp trapper.

Nb! Der man ikke har en 14 trinns trapp beregnes skår ut fra registrert tid multiplisert med 14/antall trinn. For eksempel ved trapp med 12 trinn: registrert tid: 5,4 sek x 14/12

Skåring: Alle tidene og lengdene registreres i resultatkolonnen. Man setter ring rundt den tilsvarende skåren for hver deloppgave og finner delsummen av hver kolonne. Deltester som ikke godkjennes skåres 0. Deretter legger man sammen delsummene og beregner HiMAT-skåren.

HiMAT er oversatt til norsk av Kine Therese Moen og Ingerid Kleffelgård.
For spørsmål, kommentarer og informasjon kontakt: kine.therese.moen@gmail.com eller ingerid.kleffelgard@ulleval.no

Meld fra til Gavin Williams på e-postadressen gavin@neuro-solutions.net eller gavin.williams@epworth.org.au slik at bruken av HiMAT kan spores.

Appendix 3

NTNU
Det medisinske fakultet
Institutt for sirkulasjon og bildediagnostikk

FORESPØRSEL OM Å DELTA I VITENSKAPELIG UNDERSØKELSE:

"Klinisk nytteverdi av avanserte MR-metoder og EEG ved hodeskader"

Alle pasienter og friske frivillige fra "Hodeskadeprosjektet" ledet av overlegene Anne Vik, nevrokirurgisk avdeling, og Toril Skandsen, Munkvoll Rehabiliteringssenter ved St. Olavs Hospital/ NTNU, blir hermed forespurt om å delta i nye undersøkelser.

Den nye studien skal undersøke om nye og mer avanserte MR- og EEG-metoder kan finne ut mer om årsakene til problemer som personer kan få etter hodeskade. Slik håper vi å finne ut hvordan vi best kan hjelpe pasienter i framtiden. Dette delprosjektet ledes av lege og førsteamanuensis Asta Håberg.

Sammen med resultat fra de tidligere undersøkelsene vil denne studien kunne gi ny kunnskap om hodeskader. Din deltakelse vil være særdeles verdifull. Gjennom å delta vil du være med på å gi et viktig bidrag til viten om hodeskader.

Alle forsøksdeltakere vil motta en kompensasjon på 1000 kr. De neste sidene gir mer detaljert informasjon om forsøket, blant annet hvilke undersøkelser som skal gjøres.

Ta gjerne kontakt med oss dersom du har noen spørsmål.

Vi håper du synes dette kan være interessant og ønsker å hjelpe oss til å få ny viten om hodeskader.

Med vennlig hilsen

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Telefon: 92692780

INFORMASJON OM FORSKNINGSPROSJEKTET

Det er viktig at du leser gjennom denne orienteringen før du eventuelt samtykker i å delta. Still gjerne spørsmål hvis det er noe du lurer på. Kontaktinformasjon finner du på første side av dette dokumentet.

1. Bakgrunn og målsetting for studien

Vi ønsker å finne ut om nye MR- og EEG-metoder kan bidra til klinisk nyttig informasjon hos pasienter med hodeskader. Dette vil i neste omgang kunne føre til bedre diagnostisering og dermed bedre behandling og rehabilitering av hodeskadde. Vi vil for eksempel kunne studere årsakene til oppmerksomhetsproblemer. Vi vil også kunne analysere hvilke av de aktuelle metodene som best kartlegger omfanget av hodeskader, og eventuelt kan forutsi grad av problemer i dagliglivet som pasienter kan ha etter hodeskade.

2. Hva er MR?

Vi vil i denne studien bruke følgende MR-metoder: 1. Funksjonell MRI (fMRI) er en metode som kan vise de ulike hjerneområdene som en person bruker for å gjøre en oppgave. 2. Diffusjon tensor bildedannelse (DTI) er en MR-metode som avdekker endringer i strukturen av hjernebanene, d.v.s. de nervetrådene som binder ulike områder av hjernen sammen. Ved å kombinere fMRI og DTI kan man finne ut hvordan hjernecellene bearbeider informasjon. Man kan også studere hvordan forbindelsene mellom de ulike hjerneområdene som skal samarbeide fungerer.

3. Hva er EEG?

EEG er en metode som måler hjernecellenes elektriske aktivitet ved hjelp av elektroder festet til hodebunnen.

4. Hvilke undersøkelser skal gjøres?

EEG og MR- undersøkelsene tar ca. 60 minutter hver, og vil foregå på Nevrosenteret (Nevro Vest), St. Olavs Hospital. I tillegg vil du samme dag fylle ut noen spørreskjema sammen med en av forskerne, og gjennomføre noen tester av håndfunksjon. Vi er opptatt av at hver enkelt får gjort det så godt som mulig på oppgavene. Det vil derfor bli flere pauser underveis. Det er planlagt en lengre pause mellom MR og EEG- delen slik at du får mulighet til å slappe av. Du må derfor sette av mye av dagen for å delta på testingen.

EEG

Før eksperimentet begynner vil du få påsatt en hette med elektroder på hodet. Prosjektmedarbeideren vil sørge for god kontakt mellom elektrodene og hodebunnen din ved å sprøyte inn en ufarlig gelé mellom den spesiallagede hetten og hodebunnen. Dette er viktig for å kunne måle hjerneaktiviteten på best mulig måte og tar ca. 5-10 minutter. Under eksperimentet får du få ulike oppgaver som du skal svare på ved å trykke inn bestemte knapper. Du vil også bli bedt om å sitte helt i ro og slappe av. Undersøkelsen varer i ca 60 minutter.

MR undersøkelsen

Du blir lagt på et bord som skyves et stykke inn i MR-maskinen. Maskinen er en slags tunnel som er åpen i begge ender. Under eksperimentet får du se bokstaver som du skal svare på ved å

trykke inn en knapp. Vi vil også ta noen MR-bilder der du skal ligge helt i ro og slappe av. Eksperimentet varer i ca 60 minutter.

Spørreskjema
Spørreskjemaene skal gi oss informasjon om din kognitive funksjon, livskvalitet og psykiske helse. Spørsmålene består for eksempel av en liste med en rekke vanlige plager og problemer som alle av og til har, og du skal krysse av for hva som passer best for deg. Vi legger også vekt på hvordan de nærmeste vurderer situasjonen etter skaden. Derfor vil vi også be deg om tillatelse om å spørre en av dine nærmeste pårørende om å fylle ut spørreskjema som handler om din kognitive funksjon og psykiske helse. Dersom du ikke ønsker at vi kontakter dine pårørende kan du allikevel delta i studien (se alternativ på siste side i dette dokumentet).

Undersøkelse av motorisk funksjon
Denne undersøkelsen vil kartlegge motorisk funksjon, som tempo og koordinasjon i finmotoriske oppgaver samt grovmotoriske oppgaver, som blant annet balanse. Undersøkelsen varer i ca 30-40 min.

6. Hvem kan delta?
Forsøkspersonene er kvinner og menn i alderen 16-65 år. Forsøkspersonene rekrutteres fra "Hodeskadeprosjektet" ved NTNU/St. Olavs Hospital. Både pasienter og de som deltar i kontrollgruppen inviteres til å delta. Deltagelse er ikke mulig dersom du er gravid eller har metalliske fremmedlegemer i kroppen (f.eks. pacemaker, metallsplinter, innoperert metall i hjernen eller indre øret).

6. Risiko/ubehag
Det er ingen kjent risiko knyttet til bruken av MR. Det er imidlertid noe støy fra maskinen under bildeopptakene. Det er heller ingen kjent risiko knyttet til bruken av EEG.

7. Hva skjer dersom vi finner noe uvanlig på MR-bildene eller EEG-opptakene?
EEG-opptakene og MR-bildene vil ikke granskes spesielt for å avdekke annen sykdom Det *kan* likevel forekomme at vi finner tegn på ny sykdom. Hvis vi finner slike endringer, vil du bli henvist av prosjekt- ansvarlig til oppfølging ved St. Olavs Hospital.

8. Frivillighet
Du oppfordres til å delta i forskningsstudien, men du må huske at dette er frivillig og at du kan trekke tilbake ditt samtykke på et hvilket som helst tidspunkt uten å måtte begrunne dette nærmere.

9. Tidsramme
Undersøkelsen vil gjennomføres i løpet av 2009-2010.

10. Databehandling og taushetsplikt
Alle data vil bli behandlet konfidensielt og alle som behandler data er underlagt taushetsplikt i henhold til Forvaltningsloven §13 og Helsepersonellslovens §21. Dataene blir anonymisert og skal kun brukes i forskningsøyemed. Alle data vil bli oppbevart på en betryggende måte i 10 år (jf. Nylenna utvalget).

11. Forsikring
Prosjektet omfattes av Norsk pasientskadeerstatning.

12. Økonomi
Kostnader knyttet til studiet er finansiert av Norges teknisk-naturvitenskapelige universitet og St. Olavs Hospital. Forsøkspersonene mottar økonomisk kompensasjon i form av 1000 kr.

13. Etisk vurdering
Prosjektet er godkjent av Regional komité for medisinsk forskningsetikk og meldt til Personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste A/S.

Appendix 4

SAMTYKKEERKLÆRING

Navn:_____

Fødselsdato:_____

Jeg bekrefter herved at (sett kryss):

Jeg har lest informasjonsskrivet til prosjektet *" Klinisk nytteverdi av avanserte MR-metoder og EEG ved hodeskader"*.

Ja, jeg aksepterer å være frivillig deltaker i dette forskningsprosjektet på betingelser nevnt i informasjonsskrivet.

Jeg samtykker også i at en av mine nærmeste pårørende deltar i prosjektet ved at de blir bedt om å fylle ut spørreskjema om min kognitive funksjon og psykiske helse etter skaden.

Kontaktopplysninger for aktuelle pårørende:

Navn:

Adresse:

Telefonnummer:

E-post:

Mine kontaktopplysninger:

Adresse:

Telefonnummer:

E-post:

Dato:_____

Underskrift:_____