Abstract

The objective of this review was to provide an overview of the existing knowledge of the benefits of nature-based rehabilitation for patients with impairments after acquired brain injury. Systematic searches were conducted across PubMed, CINAHL, PsycINFO and Scopus, but only seven studies could be included. Nature-based rehabilitation seems to benefit individuals with an acquired brain injury, as both motor - and sensory-motor functions, as well as cognitive functions were significantly improved. Most of the studies also found an improvement of quality of life. The benefits on anxiety and depression were not clear. The studies used different approaches, outcome measures, and study designs that made comparisons difficult. Recommendations for future studies are offered.

Keywords: Occupational therapy, nature guided therapy, wilderness therapy, forest therapy, horticultural therapy.
Introduction

The number of adults with acquired brain injury (ABI) is increasing worldwide (Johnson et al. 2016), causing severe implications for the patients, their relatives, and society in general (Haley et al. 2009). Most patients with ABI have some degree of impairments due to motor functioning problems, which is important for the quality of life (QOL). Other impairments, however, are often both complex and invisible to the surroundings (Leśniak et al. 2008; Ferro J. M. et al. 2016). Research indicate that cognitive and neuropsychiatric disorders are assessed as the most stressful problems for individuals with ABI and their relatives (Haley et al. 2009). The most common neuropsychiatric impairments are depression (defined as depressed mood and anhedonia and several other symptoms like loss of energy and psychomotor retardation. It can be subdivided into three categories according to severity (Ferro J. M. et al. 2016)). Anxiety (is mostly seen as generalised anxiety disorder and defined as an almost constant anxiety about issues that are difficult to control, and to an extend that impact the individual negatively (Ferro J. M. et al. 2016). Personality disorders (defined as changes in the personality different from previous personality pattern, e.g. lability, aggressiveness or disinhibition (Vaishnavi et al. 2009; Ferro J. M. et al. 2016). These can be part of executive dysfunctions defined as decreased mental flexibility and compromised inhibition of aggressive behaviour (Ferro J. M. et al. 2016). The emotional impairments that may appear, are defined as emotional indifference, anger or disturbances of emotional expression control (Ferro J.M. et al. 2009). Remission occurs months after the injury but is quite constant in the years to follow (Douiri et al. 2013; Ponchel et al. 2015). Cognitive disorders (defined as impaired attention, concentration, working memory and rational thinking (Ferro J.M. et al. 2009) and neuropsychiatric impairments can inhibit rehabilitation, daily activity, participation, and QOL (defined by WHO as ''Quality of life is defined as individuals’ perceptions of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns” (Development of the World Health Organization WHOQOL-BREF Quality of Life Assessment 1998; (Leśniak et al. 2008;
Sundhedsstyrelsen 2011; Pallesen 2012; Goldfinger et al. 2014). Zatzick (2008) found a dose-response relationship between the amount of impairments and difficulties in carrying out daily activities. Challenges in participating in social activities have also been shown to hamper rehabilitation (Leśniak et al. 2008; Ferro J. M. et al. 2016).

Studies indicate that the psychosocial and physical surroundings, e.g. Enriched Environment (Linden et al. 2012; Nilsson M et al. 2012) and Mindfulness Based Stress Reduction may facilitate rehabilitation as they seem to have a neuroplastic effect on the brain, and in particular on the limbic system (McEwen 2016). Natural environments have lately become a focus of interest to health professions as means to reduce anxiety and stress, and to improve the well-being of patients (Ulrich Roger S. 1986; Kaplan 1995; Stigsdotter UA and Grahn 2002; Wilson 2002; Stigsdotter UK et al. 2011). The therapeutic use of nature sustains basic neurophysiologic mechanisms (Stigsdotter UA and Grahn 2002; Lederbogen et al. 2011; Marcus and Sachs 2014; Bratman et al. 2015). Nature-based rehabilitation (NBR) is based on Annerstedts and Stigsdotters definitions and is developed as a Nordic concept (Corazon et al. 2018). It covers naturally based therapeutic interventions with natural daily activities and experiences, e.g. horticultural activities or forest therapy (FT) applied as therapeutic tools tailored specific groups (Annerstedt and Währborg 2011; Stigsdotter UK et al. 2011; Corazon et al. 2018). It is an intervention aimed to promote defined rehabilitation goals, involving plants, natural resources, and outdoor environment (Annerstedt and Währborg 2011). It can further be divided into: a. Social – and therapeutic horticulture with a therapeutic focus on garden activities led by professionals, and b. Therapy in selected environments with selected activities (Annerstedt and Währborg 2011; Stigsdotter UK et al. 2011).

Even though only few studies focusing on brain injury and nature-based rehabilitation have been published, the basic theories and understandings about nature and rehabilitation are described and seem to be able to categorize and frame various therapeutic approaches. According to Stigsdotter (2011), there are two types of natural environments: 1. Nature that is designed to affect the visitor’s
health and without therapeutic interventions, e.g. gardens in connection with hospitals and nursing homes, and 2. Nature that is designed or chosen with a therapeutic purpose (Stigsdotter UK et al. 2011). Theories and research within this field originate from several disciplines. Generally, there are four different approaches, which each have their theoretical base (Stigsdotter UK et al. 2011): 1. The Evolutionary Approach with The Attention Restoration Theory and The Aesthetic-Affective Theory, 2. The Activity Approach, 3. The Coping-Communication Approach, and 4. The Ecological Approach.

1. **The Evolutionary Approach** with the **Attention Restoration Theory** claims that the positive effects come from a healing effect of nature on the direct attention. Direct attention is localised in the evolutionary youngest parts of the brain and is used to complex problem solving, which is a mentally demanding process (Kaplan 1995; Stigsdotter UA and Grahn 2002; Stigsdotter UK et al. 2011).

   **The Aesthetic-Affective Theory**, inspired by the Biophilia Hypothesis, (Ulrich R. S. et al. 1991; Wilson 2002), is founded on the idea that humans have an inherited connection to nature and unconsciously respond positively to nature, similar to the original landscapes. Urbanisation has disrupted this connection (Stigsdotter UA and Grahn 2002; Stigsdotter UK et al. 2011; Marcus and Sachs 2014). Thus, humans in cities often experience stress-induced activity around amygdala and increased cortisol level (Lederbogen et al. 2011; Stigsdotter UK et al. 2011).

2. **The Activity Approach** is used in health interventions. This approach is a nature-based therapeutic process in which individuals experience well-being by the use of garden environments or by being close to nature (Stigsdotter UK et al. 2011). Horticultural therapy (HT), where horticultural activities, garden therapy, and garden activities are applied approaches, originate from the history of psychiatry, occupational therapy and the rehabilitation of soldiers after World War II (Nilsson K et al. 2011; Stigsdotter UK et al. 2011). Gardening offers opportunities for various activities (Stigsdotter UA and Grahn 2002; Stigsdotter UK et al. 2011).

3. **The Coping-Communication Approach** including The Scope of Meaning or The Scope of Action Theory is based on theories of Stern and Grahn and refers to occupational therapy, physiotherapy, and landscape architecture among others (Stigsdotter UK et al. 2011). It explains how communication with the environment takes place at the emotional-nonverbal and cognitive levels and depends on the ability to cope with demands of the environment. It further explains how natural environment affects neurophysiology through the emotional-nonverbal level contributing to reduce anxiety and stress (Stigsdotter UA and Grahn 2002; Ottosson and Grahn 2008; Stigsdotter UK et al. 2010; Stigsdotter UK et al. 2011).

4. **The Ecological Approach** is based on the idea that humans are an inseparable part of the biosphere. Biodiversity, nature conservation, and eco-systems are part of this approach (Stigsdotter UK et al. 2011).

The starting point for the objective of this study is based on the increasing number of patients with ABI (Johnson et al. 2016) and the following implications for the individual and the society (Haley et al. 2009; Sundhedsstyrelsen 2011). Many patients with ABI experience complications, and it is therefore important to research different ways to relieve these consequences (Sundhedsstyrelsen 2011; Bragg et al. 2015; Ferro J. M. et al. 2016; McEwen 2016). In general, many individuals and patients with ABI go “back to nature”, which is reflected by the growing interest in nature (Bragg et al. 2015), and many therapists use nature for rehabilitative purposes (Bragg et al. 2015). Though nature-based interventions seem to benefit mental health in general (Bragg et al. 2015), benefits of nature-based interventions and their usefulness within the field of neurorehabilitation are not fully explored (Annerstedt and Währborg 2011). Therefore, we attempt to shed light on interventions, that are most beneficial. Additionally, research in the field of NBR interventions for individuals with ABI
is heterogeneous, and to our knowledge, no overview of a gathered knowledge exists (Mizuno-Matsumoto et al. 2008; Annerstedt and Währborg 2011; Stigsdotter UK et al. 2011; Ho et al. 2016; Chun et al. 2017). Therefore, the objective of this scoping review was to provide an overview of the existing knowledge of the benefits of NBR for patients with impairments after ABI (Arksey and O'Malley 2005; Peters et al. 2015).

**Methods**

**Design**

This study was developed using Arksey and O’Malley’s framework, which is a five-step procedure for preparing a scoping study (Arksey and O'Malley 2005), enhancing the methodology by Colquhoun, Davis, Levac and Peters (Levac et al. 2010). The steps are: 1. Identifying the research question, 2. identifying relevant studies, 3. study selection, 4. charting the data, and 5. collating, summarizing, and reporting the results (Arksey and O'Malley 2005; Davis et al. 2009; Levac et al. 2010; Colquhoun et al. 2014; Peters et al. 2015). The basic theories and understandings about nature and rehabilitation framed the charting and collating of the included seven studies. The study followed the principles of The Declaration of Helsinki (Association 2013).

**Identifying research question**

Can NBR contribute to reduce neuropsychiatric, cognitive, behavioural, emotional, or sensory-motor impairments in adults with ABI? If yes, which benefits are seen?

**Search strategy**

A search strategy was developed using inclusion and exclusion criteria applying the Population Concept and Context (PCC) elements (Kristiansen et al. 2008). The elements contained terms related to adults with impairments from ABI, NBR targeting impairments, and the benefits of the intervention. The protocol was elaborated according to the Prisma-P 2015 guidelines (Moher et al. 2015).
**Identifying relevant studies**

The three-step literature search was conducted from February 14th – April 18th, 2017 and from November 25th, 2017 – January 25th, 2018. Studies concerning interventions using NBR and their outcomes were identified. The three steps were as follows: 1. Search PubMed to identify relevant keywords, thesaurus- and Mesh-terms and their possible combinations. 2. Search in the databases, PubMed, CINAHL, PsycINFO, and Scopus according to each database-terminology. Truncations were used when appropriate. 3. Hand search in references and search on Google Scholar and Natural England for studies that the other databases could not identify. The reference management software RefWorks was used to manage search results.

**Study selection and inclusion**

Study selection was directed by the inclusion and exclusion criteria to provide an overview of the existing knowledge related to the research questions (Kristiansen et al. 2008). Selection was made by the authors in mutual agreement. Inclusion criteria: 1. NBR interventions targeting adults with ABI. 2. Primary research studies, scoping reviews, systematic reviews, and meta-analyses reporting NBR interventions targeting the study population. 3. Literature published in peer review journals and grey literature. 4. Limits: time, January 1995 - January 2018, adults. Exclusion criteria: 1. Non-English articles (Kim SY 2003) and 2. Only abstracts available. A list of key information was employed to assist study selection (Kristiansen et al. 2008). Assessment of the methodological quality of the included studies was made according to the Prisma checklist (Moher et al. 2015).

**Charting the data**

A numerical summary was conducted to record data of the included studies by developing and testing a draft-charting table on three studies prior to the current chart (Colquhoun et al. 2014; Peters et al. 2015). The current chart exemplifies relevant key information on: first authors, year of publication, country of origin, aims, study population, sample size, methodology, intervention,
concept (theoretical framework, if mentioned), duration, outcome measures, and key findings (Arksey and O'Malley 2005; Peters et al. 2015). Descriptive statistics as effects and p-values were incorporated in a key information chart. Finally, we summarized the results narratively (Arksey and O'Malley 2005; Kristiansen et al. 2008).

**Collating, summarizing, and reporting the results**

This section comprises a descriptive numerical summary and analysis of the range, nature, and distribution of the included studies, illustrated by tables and figures. Where appropriate, a qualitative thematic analysis was applied to illuminate qualitative findings and comparing the results in order to look for gaps in research (Arksey and O'Malley 2005; Colquhoun et al. 2014).

**Results**

The literature research resulted in 10,261 studies. After screening titles, 10,252 were excluded and seven studies remained for full text reading (Figure 1). Only two articles and a conference abstract paper were found via database search (Thomas 2004; Walker et al. 2005; Palsdottir 2017), while three experimental studies (Kim M-Y et al. 2010; Ho et al. 2016) and a qualitative study (Barello et al. 2016) were found by hand search and obtained via Google Scholar. All of these, except the conference paper, were included, and further two possible records were found in a systematic review (Kamioka et al. 2014) and Google Scholar but were excluded as they only had full text in Korean or published as conference abstracts (Palsdottir 2017). An overview of the search and selection process is given in figure 1.
Participants

In the included seven studies, the total number of participants were n=168. One hundred thirty-eight had post stroke impairments (Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010; Barello et al.)
2016; Ho et al. 2016; Chun et al. 2017), 29 had impairments from traumatic brain injury (TBI), and one had impairments from a neurotoxic accident (Thomas 2004; Walker et al. 2005). Besides sensory-motor functions (Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010), the neuropsychiatric disorders, anxiety and depression (Walker et al. 2005; Chun et al. 2017), and depression were investigated (Walker et al. 2005; Mizuno-Matsumoto et al. 2008). Generalised anxiety is the most frequent disorder due to stroke. It is defined as almost constant anxiety or worry about matters to an extend that affects functioning and well-being (Ferro J. M. et al. 2016; Chun et al. 2017). Additionally, generalised anxiety include experiencing three or more DSM-5 criteria, e.g. restlessness, nervous tension, and insomnia (Ferro J. M. et al. 2016). Stroke-associated depressive disorder is defined by two main criteria - depressed mood and anhedonia. Several other symptoms, e.g. loss of energy and psychomotor retardation, are also common. Depressive disorder is subdivided into three categories according to severity. These diagnoses require clinical decisions and use of accepted diagnostic criteria (Ferro J. M. et al. 2016). Both diagnoses are associated with cognitive impairment and challenges in daily living (Chun et al. 2017).

The cognitive disorders in focus were memory disorders (Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010). The behavioural disorders in focus were executive dysfunctions such as challenged problem solving or mental flexibility (Thomas 2004; Walker et al. 2005; Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010; Barello et al. 2016) defined by Walker (2006) as difficulties in applying learned from one situation to another. Additionally, Walker (2006) points that cognitive and behavioural changes are associated with poor self-awareness, reduced motivation and initiative, that impede the ability of setting and working towards goals. Unfortunately, the studies presented no clear delineation of behavioural disorders. Also, emotional disorder as anger was only briefly mentioned (Thomas 2004) and unfortunately none of the studies presented a clear definition of emotional disorder, either. Barello (2016) does not define any of the disorders. Finally, QOL was investigated by Thomas (2004) and Ho (2016). Subjective QOL is linked to life satisfaction. A
certain level of QOL and successful rehabilitation may benefit adjustment to injury. QOLI is based on QOL theory and is used in e.g. rehabilitation outcomes evaluation. It gives an overall indication of the individual’s adjustment to injury (Thomas 2004). SSQOL is a comprehensive measurement developed for measuring health related quality of life after stroke. In this study, the Chinese version is used (Ho et al. 2016). A brief overview is provided by table 2.

**Context**

Study, year, and origin (Table 3). The studies were carried out from 2004-2017 and were originated in Europe (Italy) (Barello et al. 2016), Australia (Thomas 2004; Walker et al. 2005), or South Asia (Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010; Ho et al. 2016; Chun et al. 2017).


Location and duration. All four HT interventions took place in hospitals (Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010; Barello et al. 2016; Ho et al. 2016), in a forest (Chun et al. 2017), or in the wilderness (Thomas 2004; Walker et al. 2005). Duration was from four days till six months.

**Concept**

Methodology. The study designs varied from one RCT (Chun et al. 2017) and two other types of intervention trials, not specified or explained (Kim M-Y et al. 2010; Ho et al. 2016). Two pilot studies were part of the Australian Outward Bound Programme (OBP), one evaluated as a prospective study (Walker et al. 2005), and one as a mixed longitudinal study (Thomas 2004). The final two studies were case studies (five selected stroke patients) with tests and brain scans (Mizuno-Matsumoto et al. 2008), and a qualitative HT study (Barello et al. 2016), respectively. The interventions varied from HT (Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010; Barello et al.

Theoretical framework. The HT and garden activities are both part of the horticultural tradition and based in the Activity Approach like the FT (Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010; Stigsdotter UK et al. 2011; Barello et al. 2016; Ho et al. 2016; Chun et al. 2017). In the Australian OBP people learn and develop by means of outdoor adventure activities in supportive groups (Thomas 2004; Walker et al. 2005).

Outcome measures.

1. Motor functions. The horticultural interventions measured upper limb dexterity with the Groove Pegboard Test (GPT) (Kim M-Y et al. 2010) and independence in activities of daily living (ADL) by the Functional Independent Measure (FIM) (Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010).


3. Anxiety and depression. Anxiety was measured in the FT intervention with the Spielberger State-Trait Anxiety Inventory (STAI) and biomarkers, i.e. bodily stress level measurements with reactive oxygen metabolites (d-ROMs) and biological antioxidant potentials (BAPs) (Chun et al. 2017) in a combination with psychological screening for depression with the Beck Depression Inventory (BDI) (a self-report questionnaire) and the Hamilton Depression Rating Scale (HAM-D17) (Chun et al. 2017). The Australian OBP measured anxiety, depression, and stress by the Depression, Anxiety, and Stress Scales (DASS) (Walker et al. 2005). The horticultural experimental studies measured depression by the Geriatric
Depression Scale (GDS) and the Self-Rating Depression Scale (SDS) (Mizuno-Matsumoto et al. 2008).

4. Quality of Life. Stroke Specific quality of Life Scale (SSQOL) in a Chinese version was used in the gardening programme (Ho et al. 2016), and the outdoor adventure programmes measured QOL by Quality of Life Inventory (QOLI) during interviews (Thomas 2004).

Discussion
The present study is, to our knowledge, the first review focusing exclusively on NBR interventions for adults with ABI. The objective of this study was to provide an overview of the existent knowledge of the benefits of NBR for patients with impairments after ABI. Motor functions were significantly improved. The case study found increased brain activity, and sensory-motor functions were improved in all participants apart from one. Benefits in relation to cognitive functions were observed in three studies, and one of those showed significant results. Some studies found significant effects of FT and HT on anxiety and depression, although the benefits for depressed individuals was not clear. Most of the studies found an improvement of QOL. The interventions were built on various study designs (Thomas 2004; Walker et al. 2005; Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010; Barello et al. 2016; Ho et al. 2016; Chun et al. 2017). Consequences were defined differently, and the chosen measurement tools differed as well. Furthermore, the included studies reflected a multidisciplinary field in general. The HT interventions were mainly conducted by occupational therapists, and the other interventions were conducted by other health professionals. Most studies primarily applied the Activity Approach by using horticultural activities or being close to nature (Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010; Stigsdotter UK et al. 2011; Barello et al. 2016; Ho et al. 2016; Chun et al. 2017), and some have found inspiration in Ulrich’s Aesthetic-Affective Theory, in which exposure to nature positively affects physiology and mental health (Mizuno-Matsumoto et al. 2008; Stigsdotter UK et al. 2011; Ho et al. 2016; Chun et al. 2017). The Wilderness therapy interventions mainly applied The Coping-Communication Approach in that their
OAT is about learning to cope with ABI in supportive environments (Thomas 2004; Walker et al. 2005; Stigsdotter UK et al. 2011). Barello (2016) also shares this approach in that the horticultural activities support coping and adjusting to the new situation with ABI (Stigsdotter UK et al. 2011; Barello et al. 2016). Overall, the benefits of NBR in the seven studies seemed mixed.

**Key findings discussed**

*Motor functions.* HT with different types of making flower-arrangements seemed to have an effect on sensory-motor functions in terms of improved hand-dexterity and independence in daily living (Kim M-Y et al. 2010). In the case study, the authors assumed that HT might increase an improvement of activities in the visual and colour processing areas, the association areas, and the sensory-motor areas of the brain in post stroke patients. They concluded that HT stimulates parts of the brain that are not always stimulated by ordinary rehabilitation (Mizuno-Matsumoto et al. 2008). The other studies in this review did not test motor functions (Thomas 2004; Walker et al. 2005; Barello et al. 2016; Ho et al. 2016). Overall, very few studies have explored natural based interventions testing specific body functions. One study has explored the effect of HT activities on muscle functions of young adults, e.g. Park (2013) using electromyographic measurements, showing an effect on upper limb function. In comparison, improved muscle function may improve dexterity, but otherwise the studies may not be comparable as the target groups and outcome measures are all different. To our knowledge no other studies have tested the effects of natural based interventions on motor functions in adults in any case. Instead, studies have investigated the health promoting influence of nature on physical health in general, promoting e.g. physical activity (Bowler et al. 2010; Annerstedt and Währborg 2011; Bragg et al. 2015). In this way, the results of the seven studies included in this scoping review tally with this general effect of nature promoting physical health (Bowler et al. 2010; McMahan and Estes 2015; Soga et al. 2017). However, some authors are aware that many studies in this field have small sample sizes and diverge methods that make comparisons
impossible (Annerstedt and Währborg 2011; Bragg et al. 2015; McMahan and Estes 2015; Soga et al. 2017).

Cognitive functions. HT seems to have an effect on cognitive functions (Kim M-Y et al. 2010; Barello et al. 2016) and OBP has an effect in terms of other criteria like psychosocial adjustment and goal gaining in the Australian OBP (Thomas 2004; Walker et al. 2005). Although different approaches to assess cognitive functions were applied, participants in the studies, except from the case study, experienced an improved motivation, proactivity, and engagement in the rehabilitation (Thomas 2004; Walker et al. 2005; Kim M-Y et al. 2010; Annerstedt and Währborg 2011; Barello et al. 2016). No effect was found in the case study (Mizuno-Matsumoto et al. 2008). The study design of the case study may be the reason why no effect was seen. Particularly the small sample size, the dissimilarity of the patients, and the short duration of the interventions may be the reason. However, the authors did subsequently propose a tailor made, prolonged study (Mizuno-Matsumoto et al. 2008). It cannot be ruled out whether cognition and depression mutually affect each other negatively and thus impede progress in the severely depressed patient (Ferro J. M. et al. 2016). Whichever design (Thomas 2004; Walker et al. 2005; Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010), it can be difficult to assess in general how interacting with nature in reality impact cognition because of the diverged definitions of cognition and what it covers. The diverse measurement tools, study designs, and methodologies complicate a comparison (Thomas 2004; Walker et al. 2005; Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010). In addition, the influence of the natural environment on cognition in adults with ABI has only been explored by few studies (Thomas 2004; Walker et al. 2005; Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010). Moreover, studies of adults with schizophrenia showed marginal effect on cognition, e.g. Voruganti (2006) and Annerstedt (2011). Another study compared barren housing with greener areas and found positive differences in aggression measured via mental fatigue. Experimental studies, reviews, and meta analyses exploring cognition in general found an overall positive effect of nature on cognition (Lederbogen et al. 2011;
Berman et al. 2012; Bragg et al. 2015; Bratman et al. 2015; Ohly et al. 2016). However, the authors stress the same concern about diversity in methodologies and sample sizes when comparing studies (Bragg et al. 2015; Ohly et al. 2016).

**Anxiety and depression.** Considering the neuropsychiatric disorder, anxiety, Chun (2017) found that FT had a significant effect on anxiety. They supported their measurements with biomarkers (BAPs) (Chun et al. 2017). The effect on depression is mixed. Comparing the studies (Walker et al. 2005; Kim M-Y et al. 2010; Chun et al. 2017), both Kim (2010) and Chun (2017) found a positive effect on depression. They had a larger sample size than Walker (Walker et al. 2005) and Mizuno-Matsumoto (Mizuno-Matsumoto et al. 2008), who found no effect and had both control- and treatment groups. Different measurement tools were likewise used in these studies. Chun (2017) supported their measurements on depression with biomarkers (BAPs). These results are consistent with other findings showing that nature offers a potential for restoring mental health by improving mood and reducing anxiety and depression (Annerstedt and Währborg 2011; Lederbogen et al. 2011; Berman et al. 2012; Bratman et al. 2015; McMahan and Estes 2015). For instance, a Japanese FT-field experiment explored the physiological effect of FT measuring both biomarkers and The Profile of Mood States (POMS), and they found lowered anxiety and depression among the 280 young adults (Park et al. 2010). Still, the authors of the reviews are aware that the study field in general is heterogenous (Annerstedt and Währborg 2011; Bragg et al. 2015).

**Quality of Life.** Ho (2016) and Thomas (2004) found improved QOL. Walker et al observed changes in the direction of improved health, and this could be understood as improved QOL (Walker et al. 2005). The studies were based on programmes that were tested, and the duration of the studies differed from other similar studies (Annerstedt and Währborg 2011), which might be a strength. Although they all observed roughly similar results, their study population, study designs, and methods were different (Thomas 2004; Walker et al. 2005; Ho et al. 2016) and they might therefore not be comparable. The results of improved QOL are consistent with other findings that nature
improves the general well-being and QOL (Bowler et al. 2010; Stigsdotter UK et al. 2010; Bratman et al. 2015; McMahan and Estes 2015). Furthermore, being in nature promotes physical activity, and because of the health benefits in general NBR indirectly improve well-being and QOL and reduce depression and anxiety (Bragg et al. 2015).

No studies explored the direct effect on behaviour in terms of inhibition, judgment ability, or adjustment restructuring of ABI. However, development of cognitive functions, problem solving, and social skills during HT or nature-based programmes were explored, which could give an indirect information on behavioural impairments. The emotional functions were not mentioned in the studies. In sum, there is an indication that various NBRs influence cognitive impairments positively (Thomas 2004; Walker et al. 2005; Kim M-Y et al. 2010; Barello et al. 2016). Likewise, there is a fair indication that NBR has a positive effect on the neuropsychiatric disorders, depression (Kim M-Y et al. 2010; Chun et al. 2017) and anxiety (Chun et al. 2017) and thus, indirectly (Ho et al. 2016) and directly, QOL (Thomas 2004; Barello et al. 2016). Behavioural disorders seemed reduced as well (Thomas 2004).

Numerous fields and health professionals have contributed to research into the general knowledge of this field and into the specific topic of adults with ABI, but there is a need for exploring the use of methods and measurement tools as well as defining a common understanding of the impairments in order to deeper/fully comprehend how naturally based interventions affect the target group. We hope this study will inspire health professionals to explore the topic further and to enhance the quality of future research.

The scoping review offers a broad overview of the existing knowledge of the field and not an overview in depth. Despite an extensive search for non-pharmacological treatment of consequences of ABI, only a few studies exploring NBR interventions were found. As typical for a scoping review, we have not made an attempt to synthesise all findings despite quality assessment but have merely tried to give an overview of the existing therapeutic practice. We are thus aware that we have not
searched in all possible databases and it is possible that some studies within nature-based rehabilitation have not been included in the present study.

This review found an extensive use of validated measurement tools within the studies (Thomas 2004; Walker et al. 2005; Mizuno-Matsumoto et al. 2008; Kim M-Y et al. 2010; Ho et al. 2016; Chun et al. 2017), blood samples (Chun et al. 2017), functional magnetic resonance imaging (Mizuno-Matsumoto et al. 2008), and a mixed qualitative and quantitative longitudinal study (Thomas 2004). The differences in the studies can be seen as a strength, as they all show that NBR in general has benefits. Moreover, the current review shows that it is possible to facilitate NBR in different settings, e.g. in wild nature, forests, gardens, outdoor, and indoor. Different age groups and different types of disabilities, physical as well as cognitive, neuropsychiatric, and behavioural disabilities may benefit from these various interventions. The included studies may therefore serve as inspiration to the field. This study suggested that NBR might be a positive contribution to the rehabilitation of adults with impairments following ABI. NBR seems to positively affect consequences following ABI such as sensory-motor functions, cognitive functions, depression and anxiety, and QOL, even if implemented long after onset of ABI. Considering that research into NBR in general have shown to promote physical health and well-being, it might be apparent to assume some parallels to NBR for patients with ABI. Most of the studies were carried out in hospital or outpatient settings and being complex interventions. However, with so many adults living with the consequences of ABI for years, there is a need to further research into nature-based interventions in the different phases of ABI. At least to research the benefits of NBR in the chronic phase. Thus, we recommend research with longitudinal studies including larger sample sizes and mixed methods, in order to take the complexity of the field into account. It would likewise be desirable if a framework for NBR could be developed in order to increase validity and comparison of studies. PRISMA-ScR Checklists of the seven included studies can be sent for on application to first author

**Disclosure of interest**
The authors report no conflict of interest.

References


Palsdottir AM. 2017. A Randomized Controlled Trial of Nature-based Post-stroke Fatigue Rehabilitation (NASTRU).


Appendix 1. Search details for the database search

PubMed:


25
CINAHL:
(nature guided OR nature based AND mental health OR cognition OR stress OR depression OR behavioural OR cognitive impairment OR attention OR (ptsd or post-traumatic stress disorder) AND evidence AND intervention) AND environmental AND psychology OR public health AND nature OR horticulture OR gardening OR therapeutic landscapes OR wilderness OR forest OR biophilia AND ecotherapy OR nature assisted OR nature guided OR nature based AND mental health OR cognition OR stress OR depression OR behavioural OR cognitive impairment OR attention OR (ptsd or post-traumatic stress disorder) AND evidence AND intervention
Limiters - Published Date: 20170301-20171131; English Language; Human; Age Groups: All Adult; Language: English Search modes - Boolean/Phrase Interface – EBSCOhost Research Databases Search Screen – Advanced Search Database - CINAHL with Full Text

PsycINFO:
(((environmental psychology) OR nature OR horticultural OR garden OR (therapeutic landscape) OR wilderness OR forest) AND peer(yes)) AND (((rehabilitation of stroke) OR (post stroke) OR
(stroke survivors) OR (traumatic brain injuries) OR "nature assisted" OR "nature guided" OR "nature based" OR rehabilitation OR recovery) AND peer(yes)) AND (((mental health) OR cogniti* OR (cognitive impairment) OR (mental fatigue) OR stress OR depression OR behavioural OR (post traumatic stress disorder) OR complications OR sequelae) AND peer(yes)) OR ((autonomic nervous system) AND peer(yes))) AND (ccl.exact("Neurological Disorders & Brain Damage" OR "Neuropsychology & Neurology" OR "Health & Mental Health Treatment & Prevention" OR "Rehabilitation") AND la.exact("ENG") AND subt.exact("male" OR "female" OR "adult" OR "brain injuries") AND "humans") AND me.exact("Empirical Study" OR "Quantitative Study" OR "Longitudinal Study" OR "Followup Study") AND su.exact("Adulthood (18 yrs & older)") AND rtype.exact("Journal Article") NOT po.exact("Animal"))

Scopus:
( TITLE-ABS-KEY ( environmental AND psychology AND nature OR horticultur* OR garden OR therapeut ic AND landscape* OR wilderness OR forest OR biophilia OR evidence ) AND TITLE-ABS-KEY ( stroke OR poststroke OR stroke AND survivors OR traumatic AND brain AND injury OR acquired AND brain AND injury AND intervention AND ecotherapy OR "Nature assisted" OR "Nature guided" OR "Nature based" OR rehabilitation OR recovery ) AND TITLE-ABS-KEY ( mental AND health OR cogniti* OR mental AND fatigue OR stress OR depression OR behaviourual OR cognitive AND impairment* OR attention OR post-traumatic AND stress AND disorder OR complications OR sequelae OR sympathetic AND nervous AND system ) ) AND PUBYEAR > 2016
NB: brain injury

( TITLE-ABS-KEY ( environmental AND psychology AND nature OR horticultur* OR garden OR therapeut ic AND landscape* OR wilderness OR forest OR biophilia OR evidence ) AND TITLE-ABS-KEY ( stroke OR poststroke OR stroke AND survivors OR traumatic AND brain AND damage OR acquired AND brain AND damage AND intervention AND ecotherapy OR "Nature assisted" OR "Nature guided" OR "Nature based" OR rehabilitation OR recovery ) AND TITLE-ABS-KEY ( mental AND health OR cogniti* OR mental AND fatigue OR stress OR depression OR behaviourual OR cognitive AND impairment* OR attention OR post-traumatic AND stress AND disorder OR complications OR sequelae OR sympathetic AND nervous AND system ) ) AND PUBYEAR > 2016
NB: brain damage

Google Scholar:
Chain search March 2017, found via Google Scholar resulted in:


Chain search January 2018 (d. 6.1.2018), found in Barello et al, 2016 and searched for via Google Scholar resulted in:

Yuko Mizuno-Matsumoto: Horticultural Therapy has Beneficial Effects on Brain Functions in Cerebrovascular Diseases
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<td>mental health cognit* mental fatigue stress depression</td>
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<td>therapeutic landscape* wilderness forest biophilia</td>
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Table 2. Overview over studies related to both intervention, approach, and outcome

<table>
<thead>
<tr>
<th>Intervention and approach</th>
<th>Motor functions</th>
<th>Cognitive functions</th>
<th>Anxiety and depression</th>
<th>Depression</th>
<th>SSQOL/ QOLI</th>
<th>Behavioural functions</th>
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<tbody>
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<tr>
<td>Year/origin</td>
<td>Objectives</td>
<td>Study population and sample size and type of ABI and consequences</td>
<td>Methodology</td>
<td>Intervention and duration</td>
<td>Theo. frame-work</td>
<td>Outcome measures</td>
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<td>------------</td>
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<td>(Ho et al. 2016) (Taiwan)</td>
<td>How plants, gender, and time after stroke onset influenced QOL.</td>
<td>Thirteen participants in two groups 6-18 months after stroke onset, six participants completed the study. Neuropsychiatric disorder: Depression. Cognitive disorders: Energy level, language and thinking.</td>
<td>Experimental study analysed with a replicated factorial design</td>
<td>Examining improvements in quality of life by taking care of plants with short-term cycles or long-term cycles. Twenty-six times in total once a week in six months.</td>
<td>TG</td>
<td>SSQOL - Twelve areas evaluated: Energy level, family roles, language, mobility, mood, personality, self-care, social roles, thinking, vision, upper-extremity function, and work function.</td>
</tr>
<tr>
<td>(Chun et al. 2017) (South Korea)</td>
<td>Whether FT was effective on depression and anxiety.</td>
<td>Fifty-nine participants with chronic stroke was randomly assigned to a forest group or an urban group, respectively, and assigned to the same treatment programs. Neuropsychiatric disorders: Depression and anxiety.</td>
<td>Randomized controlled trial</td>
<td>FT programme in a recreational forest. Duration and type of activities the same in both groups. Four days and three nights.</td>
<td>FT</td>
<td>Psychological evaluation: BDI, HAM-D17 and STAI. Biomarkers expressing bodily stress: measuring ROMs and BAPs</td>
</tr>
<tr>
<td>(Mizuno-Matsumoto et al. 2008) (Japan)</td>
<td>Whether HT was effective to improve brain functional activity.</td>
<td>Five participants (onset of ABI: 6 months to 2 years and 8 months) with several cognitive consequences, e.g. dysarthria and aphasia. Also, four patients were moderate depressed and one severely depressed.</td>
<td>Case study</td>
<td>Participating in HT in three steps: Imagining nature, designing a flowerbed, and planting a tree; HT supplemental to usual medical and physical treatment at hospital. Twenty times in one month.</td>
<td>HT</td>
<td>FIM, FMRI, SDS, DSM IV-TR and ADL before and after HT.</td>
</tr>
<tr>
<td>Author(s) and Year</td>
<td>Location</td>
<td>Sample Description</td>
<td>Intervention</td>
<td>Psychological Outcome Measures</td>
<td>Client Ratings</td>
<td>Additional Notes</td>
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<tr>
<td>Barello et al. 2016 (Italy)</td>
<td>Twenty-two poststroke patients (first-ever stroke) physically active, interested in engaging in gardening therapy, cognitive able and medical condition favourable for participation, aged &gt; 50 years. MMSE &gt;24/30, Cumulative Index Rating Scale &lt; 5, conversation ability in Italian. Excluded patients with neuropsychiatric disorders.</td>
<td>Qualitative phenomenological study, semi-structured interviews at the end of the intervention.</td>
<td>Interventions along usual physical rehabilitation. Garden activities were e.g. planting herbs, sowing, digging, harvesting, flower arranging, shaping bushes. Ten times weekly of 60 minutes each.</td>
<td>TG</td>
<td>Diary about the activity after each session to express feelings and experiences. Five themes revealed: 1. The restorative effect of nature, 2. TG as a protected self-expression space, 3. Plant as a catalyst of patients-therapist relationship, 4. Contact with nature as a boost for self-efficacy, 5. TG as a bridge between the hospital and the world.</td>
<td>The patients perceived it as a way to cultivate their active role in medical care, enabling proactive and positive attitude towards coping disease.</td>
</tr>
<tr>
<td>Walker et al. 2005 (Australia)</td>
<td>Eleven participants with severe ABI attended the outdoor adventure course, skill development, and goal-based learning programme. Participants had clinically significant executive dysfunction, e.g. reduced problem-solving ability, mental flexibility, memory impairment, and slow information processing.</td>
<td>A prospective repeated measures design with a single opportunity sample.</td>
<td>Rehabilitation programme in three steps: 1. Nine months. Participants fund-raised to pay half the cost. 2. 9-day course: Bushwalking and climbing plus goals to stage three. 3. 4 months: Participants worked on individual goals in structured meetings.</td>
<td>OAT</td>
<td>Goal attainment and changes on psychological variables (self-rating and family rating). Differences analysed using Wilcoxon Signed Ranks Test. Psychological outcome measures: DASS, GWB and EBIQ. The participants’ subjective ratings of the 3 steps of the program and its overall importance to their rehabilitation were averaged on a Likert scale of 1–10. ADL, difficulties in managing emotions, coping with ABI, and distinct lack of QOL. QOL was applied to examine global indications of participants’ adjustment to injury.</td>
<td>80.8% goals were achieved. Psychological scores over time and psychological health - NS. The overall importance of the rehabilitation calculated were to be 7.1, 9.5, 6.0 and 7.0, respectively. QOL*** Participants regularly attending follow-up group stages of the programmes had greater gains than non-attendees***</td>
</tr>
<tr>
<td>Thomas 2004 (Tasmania)</td>
<td>Twenty-two participants with ABI. Fourteen in treatment group and a demographically matched control group of 8. Participants: Self-selected adult volunteers, present or former clients of Rehabilitation Programme.</td>
<td>Two pilot study programmes. Mixed qualitative and quantitative longitudinal design.</td>
<td>The programme was developed and tested in three steps: 1. Group based fundraising to pay half the cost. 2. Nine-day outdoor adventure course. Activities: caving, rafting, bushwalking and climbing plus goals to stage three. 3. Group work on personal insights and gains as relationships, independence and restructuring tasks through problem-solving.</td>
<td>OAT</td>
<td>The patients perceived it as a way to cultivate their active role in medical care, enabling proactive and positive attitude towards coping disease.</td>
<td>80.8% goals were achieved. Psychological scores over time and psychological health - NS. The overall importance of the rehabilitation calculated were to be 7.1, 9.5, 6.0 and 7.0, respectively. QOL*** Participants regularly attending follow-up group stages of the programmes had greater gains than non-attendees***</td>
</tr>
</tbody>
</table>

**Significant=p<0.05; NS=Non-significant. Abbreviations: ABI=Acquired Brain Injury; ADL=Activities of Daily Living; BAPs=Biological Antioxidant Potential; BDI=Beck Depression Inventory; DASS=Depression Anxiety Stress Scale; DSM IV-TR=Diagnostic and Statistical Manual of Mental Disorders Fourth Ed.TR; EBIQ=European Brain Injury Questionnaire; FIM=Functional Independent Measure; FMRI=Functional Magnetic Resonance Imaging; GDS=Geriatric Depression Scale; GPT=Grooved Pegboard Test; GWB=The General Well-Being Schedule; HAM-D17=Hamilton Depression Rating Scale; HOT=horticultural occupational therapy; HT=Horticultural Therapy; MMSE=Mini-Mental State Examination; OAT=Outdoor Adventure Therapy; QOL=Quality Of Life; QOLI=The Quality of Life Inventory; ROMs=Reactive Oxygen Metabolites; SDS=Self-rating Depression Scale; SSTAI=Spielberger State-Trait Anxiety Inventory; TG=Therapeutic gardening.**