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Biomarkers of Stress and Exercise-Induced Affect in Connection with Physical Activity in Nature

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FOREWORD

The work on this thesis have been rewarding yet challenging. While endocrinology has long been a passion, health benefits of nature were new to me. The allure of working with cortisol is what led me to work on this topic, and I was not disappointed. I have learned much about this important stress hormone that I will use in the future. Not to mention my newfound appreciation of nature. Being aware of, and turning to nature helped during the stressful times of working on my thesis.

I am very grateful to my primary tutor Giovanna Calogiuri at Hedmark University College for her patience, support and advice. As well as my secondary tutor Grete Grindal Patil at NMBU for invaluable advice. I would also like to thank Tom Crocker, Maria Thi Le and Markus Lund Vevle for help with proof reading and structuring, and my family and friends for support and patience during the work on this thesis.

Kim Andersson
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ABSTRACT

Psychosocial stressors can contribute to chronically stimulate the stress-response system, possibly leading to disease if not adequately "shut off". Physical activity in nature, called green exercise, is often used a means of stress-relief.

A literature review of scientific literature on benefits of green exercise was conducted, with special focus on cortisol and emotions. Twenty-six articles were included. Results showed low-intensity green exercise, such as walking, led to greater improvements in emotions than in built environments. The results regarding effects on cortisol were inconclusive.

The second part of this study was based on a randomised controlled trial conducted in 2012. The objective of this study was to examine the effects of green exercise on the cortisol awakening response (CAR) of healthy adults, and explore a possible correlation with exercise-induced affect. Fourteen participants (7 male and 7 female, mean age 49±8 years) were assigned to a green exercise or indoor exercise setting. The intervention consisted of two exercise sessions on separate days, involving a biking and strength training part. The area under the curve with respect to the ground (AUC_G) and area under the curve with respect to increase (AUC_I) for the CAR was calculated, and analysed using between-subject analysis of covariance.

The green exercise group had significantly lower AUC_I for the CAR than the indoor exercise group. Difference for AUC_G between settings did not reach significance. A significant positive correlation was observed between tranquillity and AUC_G. No other significant correlations were found.

Overall, the findings from this thesis are suggestive of beneficial effects of green exercise on emotions, and possibly of a lower physiological stress response. Further studies on larger samples are required.

ABSTRAKT

Psyko-sosiale stressorer kan bidra til og kronisk stimulere stress-responssystemet, og mulig lede til sykdom om ikke tilstrekkelig ”skrudd av”. Fysisk aktivitet i naturen, kalt ”grønn trening”, blir ofte brukt som avlastning mot stress.

En litteraturgjennomgang av vitenskapelig litteratur om helsefordeler ved ”grønn trening” ble gjennomført, med spesielt fokus på kortisol og følelser. Tjueseks artikler ble inkludert. Resultatene viste at aktivitet med lav intensitet, som for eksempel gåing, førte til større følelsesmessig forbedring enn i bygde omgivelser. Resultatene for kortisol var mangelfulle.

Den andre delen av studien var basert på en randomisert kontrollert studie utført i 2012. Formålet med denne oppgaven var å undersøke effekten av ”grønn trening” på kortisol oppvåkingsrespons (CAR) hos friske, voksne individer, og utforske en mulig relasjon til trenings-indusert affekt. Fjorten deltagere (7 menn og 7 kvinner, gjennomsnittsalder 49±8 år) ble fordelt til en ”grønn trenings-” eller innendørs treningsgruppe. Intervensjonen besto av to treningsøkter på separate dager, bestående av en sykkel- og styrkeøkt. Område under kurven med hensyn til null (AUC_G) og område under kurven med hensyn til økning (AUC_I) ble kalkulert, og analysert ved hjelp av ”analysis of covariance”.

Gruppen som trente i natur hadde signifikant lavere AUC_I for CAR enn gruppen som trente innendørs. Forskjellen for AUC_G nådde ikke statistisk signifikans. En signifikant positiv korrelasjon ble observert mellom ” tranquillity” og AUC_G. Ingen andre signifikante korrelasjoner ble funnet.

Samlet sett indikerer funnene fra denne oppgaven at ”grønn trening” er fordelaktig for følelser, og fører mulig til en lavere fysiologisk stressrespons. Videre studier på større utvalg er nødvendig.

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Abbreviations

η_p^2 – Partial-eta squared

ACTH – Adrenocorticotropic hormone

ANCOVA – Analysis of covariance

ART – Attention restoration theory

AUC – Area under the curve

AUC_G – Area under the curve with respect to the ground

AUC_I – Area under the curve with respect to increase

CAR – Cortisol awakening response

CRH – Corticotropin-releasing hormone

HPA – Hypothalamic-pituitary-adrenal

ICC – Intraclass correlation

PAAS – Physical activity affect states

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1.0 BACKGROUND

The theme of this thesis is green exercise (physical activity in nature) and stress-reduction. Preliminary an introduction (Chapter 1) covers the fundamentals of stress, emotions, health challenges associated with chronic stress, allostasis and theoretical perspectives on health benefits from interacting with nature. The introduction ends with objectives, research questions and hypotheses on which the work is based.

The thesis is then divided in two sections. Study 1 is a narrative review of the scientific literature on green exercise and effects on cortisol and emotions in order to give an extensive overview of the subject. A systematic approach to the literature search was used, and is described in the methods chapter (Chapter 2), though the results are synthesised in a narrative manner (Chapter 3). The results are further divided in effects of green exercise versus urban environments and indoor environments, followed by a discussion of the literature review (Chapter 4).

Study 2 uses data from an experiment conducted in 2012 on green exercise compared to indoor exercise. This study focuses on the effects on the cortisol awakening response and how it may relate to exercise-induced affective states. Part of the work with this thesis involved computing an *area under the curve* for the *cortisol awakening response*. This work is described in the methods chapter (Chapter 5) for study 2. The area under the curve-calculation was my contribution to an article using the same dataset as this thesis (Calogiuri et al., in press). The article will be published in *WORK: A Journal of Prevention, Assessment & Rehabilitation* during 2014/2015. The area under the curve for the cortisol awakening response and affect is analysed using quantitative methods (Chapter 6). The results and methodology are subsequently discussed (Chapter 7). An overall discussion on the public health implications of the findings is given (Chapter 8), before a conclusion and recommendations for future studies ends the thesis (Chapter 9).

In the past years many studies have focused on psychological and physiological restorative effects of interacting with nature. However, to the best of my knowledge no previous studies have measured the effects of green exercise on the cortisol awakening response.

1.1 Introduction

Work-related stress is considered one of the major social health determinants in modern society and is believed to have a substantial impact on the public health burden in its relation to a range of deleterious health outcomes (Tennant, 2001; Helsedepartementet, 2003; Grahn & Stigsdotter, 2003; Lovallo, 2010). In addition to occupational stress, other psychosocial stressors, such as family and health concerns, can contribute to chronically stimulate the stress-response system (Lovejoy, 2005). Deficient regulation of physiological processes following chronic stress is seen as a potential cause of the development of disease (Juster et al., 2010). One of the possible ways in which chronic stress can contribute to such an advancement of ill health is through chronic hypertension from constant high arousal levels, which damages blood vessels, thereby leading to atherosclerosis and cardiovascular disease (Sterling & Eyer, 1988). Hypertension is one of the five leading mortality risks globally (along with smoking, high blood glucose, physical inactivity and obesity), raising the risks of cardiovascular disease and cancer (WHO, 2009). High blood pressure alone accounts for as many as 7.5 million deaths yearly worldwide**.** As these diseases are related to lifestyle and environment, they warrant research into alternative ways to prevent disease and promote health (Nilsson et al., 2011).

Health promotion entails empowering people to take control over and improve their health, thereby shifting focus to health determinants instead of diseases (WHO, 1986). Health was defined by WHO in 1946 as complete physical, mental and social well-being, and not merely the absence of disease or infirmary (WHO, 1946). The Ottawa Charter adds that in order to reach this state of health, one must be able to identify and reach one's ambitions, satisfy one's needs and cope with or adapt to the environment (WHO, 1986). It further introduced the need for establishing supportive environments, and states that people and their environments are indivisibly linked. Preservation of natural environments and recourses is advocated by the charter, which considers this essential for any health promotion strategy. Developing healthy, supportive environments requires intersectoral action between health and other sectors. Intersectoral action is defined as action by sectors outside the health sector that affects health outcomes, with or without collaboration with the health sector (WHO, 2008).

The natural environment is commonly considered beneficial to health and people often turn instinctively to nature for stress relief (Maller et al., 2005; Nilsson et al., 2011). Recommending a walk in the forest was the first advice respondents would give a friend who felt stressed or worried, according to a Swedish survey (Grahn & Stigsdotter, 2003). A Norwegian survey found that 79% of 1,059 respondents said that walking in nature as a way of "getting away from hassle and stress" was "very important" or "quite important" in a Norwegian survey (Vaagbø, 1993). In another Norwegian survey, 95% of respondents reported that they perceive regular, direct interaction with nature to be a substantial element of "the good life" (Miljøverndepartementet, 2001). Living in close proximity to urban green space can also be beneficial, as having access to natural areas within a 3 km radius around one's home significantly reduces the number of health complaints and increases perceived general health in relation to stressful life events (Van den Berg et al., 2010), and living in areas with a high percentage of green space is related to lower levels of stress, indicated by reduced cortisol levels amongst participants (Roe et al., 2013).

In recent years there has been a growing interest in the relationship between being active in natural environments and health (Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, Nature and the Environment , 2004; Yerrell, 2008; Townsend & Weerasuriya, 2010; Barton & Pretty, 2010; Mitchell, 2013). There is a belief that spending time in natural environments is beneficial to human health. Substantial evidence exist that physical activity alone has positive mental and physical health effects (Petruzello et al., 1991; Salmon, 2001; Carron et al., 2003; Biddle & Mutrie, 2008; Henriksson & Sundberg, 2008; Penedo & Dahn, 2008). However, it has been suggested that physical activity in a natural environment, termed *green exercise*, may have additional benefits over exercise performed indoors or in urban settings (Pretty et al., 2003; Thompson Coon et al., 2011). Physical activity is defined as bodily movement via skeletal muscles that causes expenditure in energy (Caspersen et al., 1985).

Almost 80% of the Norwegian population lives in urban areas, and in a Norwegian survey among users of urban forests, physical activity was found to be a fundamental part of the reason for visiting the forests, but the mental well-being associated with the consequent stress reduction appeared to be an underlying cause (Gundersen, 2009). A survey of users of urban forests and parks in Switzerland also reported a significant reduction of perceived stress after being in natural environments, with higher stress reduction for jogging and biking than for walking and relaxing (Hansmann et al., 2007). The findings from Norway and Switzerland are corroborated by a Swedish study finding that people were less affected by stress the more time they spent in urban green space (Grahn & Stigsdotter, 2003).

1.2 Stress and the HPA axis

In order to understand the harmful effects of chronic stress, it is necessary to understand what stress is and what causes it. To modern humans the stress response can be perceived as an inconvenience, manifesting as psychological states such as anxiety, irritability and the inability to concentrate, but the evolutionary physiological purpose of the stress response is to protect the organism and divert energy to the tissues and organs where it is needed the most (Lovejoy, 2005). Much of the stress response occurs through a regulated system called the hypothalamic-pituitary-adrenal axis (HPA axis). Reacting to a stressful event, the hypothalamus (a small area in the brain) secretes corticotropin-releasing hormone (CRH), which stimulates the pituitary gland to release adrenocorticotropic hormone (ACTH) to the bloodstream (Golden et al., 2011). This in turn stimulates the adrenal gland to release the glucocorticoid called cortisol.

Cortisol is produced in the middle layer of the cortex of the adrenal gland (Harvey & Ferrier, 2008). Its production is controlled by the hypothalamus via the pituitary gland. The main effects of cortisol on the body are increased gluconeogenesis and protein catabolism, resulting in increased serum glucose levels (providing energy to the body), anti-inflammatory action and reduced immune function. The basal activity of the HPA axis has a clear diurnal rhythm, with the highest cortisol production during the second half of the night, a peak in the early morning and a gradual decline throughout the day (Fries et al., 2009).

Cortisol concentration increases in response to both physical and psychological stress (Kirschbaum & Hellhammer, 1989). Examples of situations shown to increase cortisol are public speaking, having blood drawn, exams, horror movies, and moderate to vigorous exercise. The easiest way to measure cortisol is via saliva samples (Golden et al., 2011). Self-administered saliva sampling has the advantage over blood sampling in that it is non-invasive, allows for repeated measures without medical personnel, and has a strong correlation to the free cortisol levels in blood, plus the saliva samples remain stable at room temperature for at least 1 week.

1.2.1 Cortisol awakening response

In addition to the peaks seen in the diurnal cycle, there is a small increase in cortisol levels within 20–30 minutes after awakening, called the cortisol awakening response (CAR) (Fries et al., 2009). The CAR is distinguished by a sudden release of cortisol into the blood stream of around 38–160% of the level upon awakening (Clow et al., 2004; Fries et al., 2009). It is believed to reflect the capacity of the adrenal gland to respond to stress and can thus be used to detect differences in HPA axis tone as a function of continuous exposure to stress (Wüst et al., 2000; Golden et al., 2011). However, the precise function of the CAR is unknown (Fries et al., 2009). Because of the simplicity of the procedure, having participants take saliva samples themselves is the most frequently used way of obtaining samples for CAR measurement (Clow et al., 2010). It is most commonly measured in 15-minute intervals from awakening to 30–60 minutes after.

The repeated measurements of an individual's cortisol awakening response are often summarised as an *area under the curve* (AUC) (Pruessner et al., 2003). The AUC condenses several observations into a single value, thereby simplifying the statistical analysis. Two area measures can be calculated from the CAR: the *area under the curve with respect to the ground* (AUC_G), and the *area under the curve with respect to increase* (AUC_I). Figure 1 shows a graphical representation of the two area measures for a CAR with four data points.

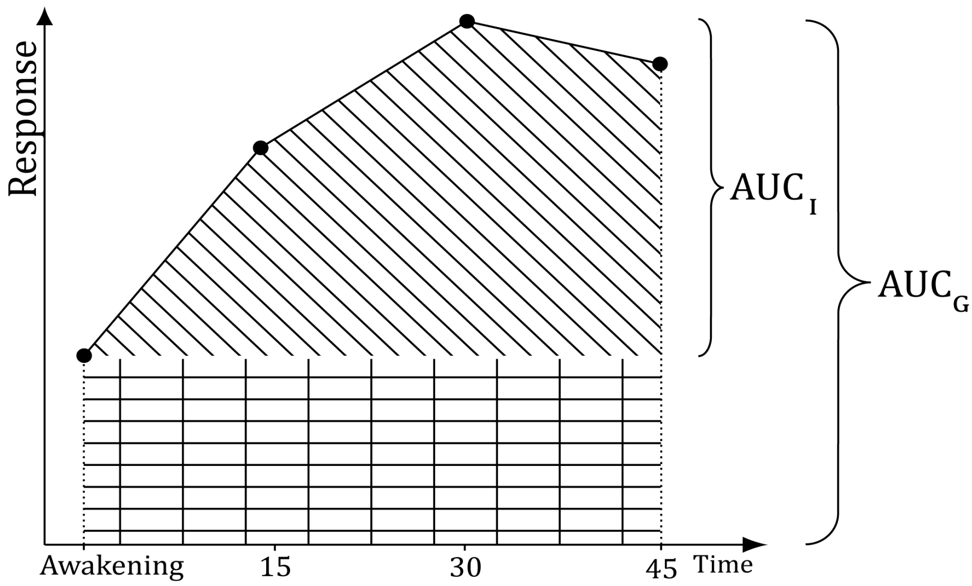

Figure 1: Illustration of the area under the curve for the cortisol awakening response. AUCG = Area under the curve with respect to the ground. AUCI = Area under the curve with respect to increase. Adapted from Clow et al. (2010) and Fekedulegn et al. (2007).

The HPA axis is highly responsive to stress; it is believed that chronic stress causes permanent changes to the HPA axis function, and the association between elevated CAR and high chronic stress is considered well established (Wüst et al., 2000; Fries et al., 2009). Furthermore, a meta-analysis found job stress and general life stress to be significantly positively associated with both AUC_G and AUC_I (Chida & Steptoe, 2009).

1.3 Emotions and health

Even though distinctions are sometimes made between *emotions*, *affect* and *mood* concerning the duration of the feelings, the terms are often used interchangeably in the scientific literature (Carron et al., 2003; Pressman & Cohen, 2005). For the purpose of this thesis the terms will also be used interchangeably. The literature review therefore includes both "affect" and "mood" (and their accompanying subscales, e.g. anger, fatigue, tranquillity, anxiety, liveliness and revitalization) as emotional outcomes of interacting with nature. However, only "affect" is used for the experimental study.

Positive affect is considered beneficial to health (Pressman & Cohen, 2005; Dockray & Steptoe, 2010). There is considerable evidence linking positive affect to reduced morbidity (e.g. stroke, recurring coronary problems, the common cold and accidents), as well as self-reported pain and health (Pressman & Cohen, 2005). Similarly, being in a state of *negative affect* over a prolonged time is associated with increased risk of cardiovascular disease, type 2 diabetes and premature mortality (Steptoe et al., 2005). A positive affective state may be protective, but the mechanism through which this is mediated is not fully understood. It is believed that a variety of biological processes facilitate the effects of positive affect on health (Dockray & Steptoe, 2010). One potential pathway for positive affect's influence on health is through direct effects on hormones released by the HPA axis (Pressman & Cohen, 2005). Positive affect has been found to reduce activation of neuroendocrine, autonomic, immune and inflammatory pathways (Dockray & Steptoe, 2010). Production of cortisol is found to be responsive to emotions (Pressman & Cohen, 2005), and there is a tendency of lower cortisol in people with high positive affect (Pressman & Cohen, 2005; Dockray & Steptoe, 2010). Affect is also believed to influence the CAR, and an inverse association between both AUC_I and AUC_G and positive affect has been established (Chida & Steptoe, 2009).

1.4 Stress and the body – allostasis

The principle of homeostasis states that there is a physiological process that maintains stability in the body by keeping internal conditions relatively constant (Sterling & Eyer, 1988). It further states that health is a condition in which all physiological parameters have "normal" values. Negative feedback corrects deviations from biological set points, and these deviations from the normal range are considered “unhealthy”. However, in 1988 Sterling and Eyer introduced the term *allostasis*, meaning stability through change, as an “alternative” to homeostasis. They claim that the organism must vary the parameters of its internal environment and match them to external environmental demands in order to maintain stability. Allostasis consists of a range of dynamic actions that trigger various neuroendocrine hormones, immune factors and autonomic nervous system mediators, used to maintain homeostasis when the organism experiences a stress response (Golden et al., 2011). These short-term adaptive actions of allostasis are protective to the body; however, if not adequately “shut off” after the stressful event has passed, the effects can be damaging in the long term (McEwen & Seeman, 1999). McEwen and Stellar therefore introduced the term *allostatic load* to represent the impact from the “wear and tear” an organism experiences following repeated stressful events, or an inability to turn off the stress response (McEwen & Stellar, 1993). Continuous exposure to glucocorticoids and other stress hormones (i.e. increased allostatic load) is associated with various metabolic and neurological disorders and can lead to infertility, growth inhibition, reduced immune function, chronic fatigue, impaired sleep, cardiovascular diseases and cancer (McEwen & Seeman, 1999; Lovejoy, 2005; McEwen, 2006; Golden et al., 2011). Cortisol is one of the allostatic load biomarkers called primary mediators (Juster et al., 2010). By measuring interactions between primary mediators and their effects, it may be possible to detect individuals at high risk of developing allostatic overload (Wüst et al., 2000; Juster et al., 2010). Furthermore, by implementing interventions that prevent or reduce the effects of stress, it may be possible improve physical and mental health (Juster et al., 2010).

1.5 Health benefits of nature – a theoretical perspective

As mentioned above, turning to nature when stressed is a common practice (Grahn & Stigsdotter, 2003; Hansmann et al., 2007; Gundersen, 2009). Why is this? What is it about nature that may cause people to feel more restored? Restoration or stress recovery involves a process of renewing psychological (e.g. emotions) and physiological (e.g. HPA axis response) capabilities (Ulrich et al., 1991; Hartig, 2004). The terms *restoration* and *stress recovery* will be used interchangeably in this thesis. Humans' feelings of belonging to nature may be attributed to an environmental preference for aesthetics in nature that signal conditions relevant to human welfare and comfort (Hartig et al., 2011). The idea that humans inherently tend to focus on life and lifelike processes is called the biophilia hypothesis (Wilson, 1984). These can be processes observed in e.g. plants, animals and natural landscapes (Hartig et al., 2011). The biophilia hypothesis emphasises the positive responses people have towards nature. Reacting positively to environmental cues such as potential water and food sources and safe shelters, as well as reacting negatively to cues such as predators and poisonous food, could have caused significant evolutionary adaptations.

There are two theoretical perspectives that elucidate potential mechanisms of stress-reducing effects of nature. The first theory is Roger Ulrich's *psycho-evolutionary theory*, which proposes that nature has intrinsic properties that can enable recovery from psychophysiological stress through more positive feelings, positive changes in physiological responses, and sustained attention (Ulrich et al., 1991). The properties associated with restoration from stress are vegetation, spatial openness, presence of pattern or structure, and water features. The theory claims that humans are predisposed to respond positively to such natural features, as they would have been beneficial to survival and well-being in the wild. During early evolution of man, individuals that quickly learned that nature had restorative effects following stressful activities may have been rewarded during evolution. In addition, having approach behaviour towards natural settings with qualities beneficial for survival in times without stress, such as access to food and water and low risk of predators, could likely have caused the proliferation of these individuals.

Unthreatening natural environments should, from an evolutionary point of view, elicit a rapid increase in positive affect and parasympathetic nervous activity (i.e. feeling calm) (Ulrich et al., 1991). Sustained sympathetic activity and physiological arousal are fatiguing and lead to chronic cardiovascular and endocrine responses that over time would have been detrimental to health. The first hominids evolved around 5 million years ago, and until very recently (in evolutionary terms) humans were embedded in the natural environment (Frumkin, 2001). Evolutionary perspectives assert that we are therefore physiologically and psychologically adapted to natural settings to a degree and that, assuming they are unthreatening, they hold more restorative properties than do urban environments (Ulrich et al., 1991). Ulrich et al. (1991) also empirically demonstrated that watching videos of unthreatening natural environments following a stressor resulted in greater positive emotions and decreased physiological arousal than watching videos of urban environments.

The second theory is Kaplan and Kaplan's attention restoration theory (ART), which suggests that nature facilitates restoration from attention fatigue (Kaplan, 1995). Sustaining directed attention on an activity that is not inherently interesting requires an inhibiting effort, which suppresses attention paid to distracting stimuli, thereby causing attention fatigue. Kaplan proposes that fascination leads to an effortless attention that is not susceptible to fatigue, thus giving directed attention the chance to rest. An environment that provides opportunities for reducing directed attention fatigue is referred to as a restorative environment. Fascination is a central part of a restorative experience, in addition to three other components that contribute to making an environment restorative: being away (perception of "mental distance" from everyday demands), extent (the environment has the richness, size and scope to engage the mind) and compatibility (a coherence between what one would like to do, and what is possible to do in the environment). Kaplan further states that nature has all four components of a restorative environment and that experiences in natural environments can aid in recovery of directed attention as well as help mitigate stress.

However, unlike Kaplan's ART, the psycho-evolutionary theory argues that the primary reactions to nature are immediate and unconscious emotional responses that are vital in influencing attention, cognition, and behavioural and physiological responses, while ART is based on cognitive appraisal of the environment (Ulrich et al., 1991).

1.5.1 Philosophy of science - epistemology

In research concerned with health promotion, it is common to apply existing theories to develop effective interventions (Klepp, 2007). These theories can in turn be used to develop hypotheses to be tested deductively (hypothetic-deductive method) (Bjørndal & Hofoss, 2010). According to Karl Popper, the testability of a theory is a fundamental criterion of science (Popper, 2005). By testing the hypothesis through experiment, one can conclude that the hypothesis is either strengthened or needs to be rejected (Bjørndal & Hofoss, 2010). In this thesis the psycho-evolutionary theory is the basis for the hypotheses stated in subchapter 1.6.

1.6 Objectives and research question

The objectives of this study are to conduct an extensive literature search on the topic of cortisol and emotional responses in relation to green exercise and, furthermore, to calculate the AUC based on the CAR, investigate the effects of green exercise on the CAR of healthy adults, and explore whether the CAR correlates with exercise-induced affective states.

Three research questions have been formulated for this thesis, one for the literature review and two for the experimental study:

1. Literature review: What is the current knowledge regarding the additional benefits of green exercise in healthy adults, as compared to built environments, with special focus on cortisol and emotional states?
2. Experimental study: How does the cortisol awakening response differ between green exercise and exercise in indoor environments?
   Hypothesis 1: The cortisol awakening response is lower after green exercise than after similar exercise indoors.
3. Experimental study: What is the relationship between the cortisol awakening response and exercise-induced affect after green exercise and exercise in indoor environments?

Hypothesis 2: The cortisol awakening response is inversely associated with exercise-induced positive affect and tranquillity, and directly associated with negative affect and fatigue.

STUDY 1 – LITERATURE REVIEW

Narrative reviews are comprehensive syntheses of previously published studies in a narrative manner, summarizing the content of the included studies in a condensed format (Green et al., 2006). The purpose of this narrative review is to synthesise the existing literature to give an extensive overview of the subject and to ascertain whether there is an empirical basis to claim that green exercise has more positive effects on cortisol and emotional responses than interacting with urban or indoor settings. The literature review contains only quantitative studies on healthy (non-clinical) populations. Furthermore, only studies with a control group are reviewed.

2.0 METHODS

The search for relevant articles was conducted in databases *PubMed* and *ISI Web of Knowledge* during January 2014. In addition, the bibliographies of included articles were browsed for additional relevant articles. Figure 2 summarizes the literature search process. Prior to the main searches, the databases as well as *Google Scholar* were used to identify possible relevant keywords. Keywords and Boolean operators used were: (natur* OR "natural environment" OR forest* OR park OR garden OR landscape OR outdoor OR outside) AND ("green exercise" OR "physical activity" OR exercis* OR walk* OR run*) AND (cortisol OR restorati* OR "positive affect" OR PAAS OR "physical activity affect scale"), where * identifies all variations of the base word (e.g. searching for *restorati** returns results including "restoration" and "restorative"). In *PubMed* search limits were set to only include studies conducted on humans, while in *ISI Web of Knowledge* the search was restricted to relevant research domains (science technology and social sciences) and research areas (environmental sciences ecology, biodiversity conservation, endocrinology metabolism, physiology, public environmental occupational health, biochemistry molecular biology, sport sciences, neurosciences neurology, behavioural sciences, biomedical social sciences, forestry, psychology, life sciences biomedicine other topics, biophysics and evolutionary biology). No other limits were set for the literature serach.

The definition of activity by skeletal muscles that causes expenditure in energy (Caspersen et al., 1985) was used when including articles. Environments are often perceived as natural if human made features are absent and contain predominately vegetation and/or water (Ulrich et al., 1991). A less strict definition was used for this literature review, and all settings containing green space were included, such as university campuses or urban parks. Inclusion criteria were adult subjects, cortisol reported as an outcome (salivary, urinary or serum), mood or affect reported as an outcome, and some form of physical activity in actual nature. Exclusion criteria were lack of a control group, non-English language, clinical population or qualitative research design studies.

3.0 RESULTS

Searching the two databases resulted in a combined total of 2,338 articles. After an initial screening of titles based on the exclusion criteria, 63 abstracts were chosen for closer scrutiny, and 47 full-text articles were downloaded for eligibility assessment. A total of 25 articles were excluded based on the exclusion criteria after reading of the full text, leaving 20 original articles and two reviews eligible for inclusion. Reference lists of included studies and reviews revealed four additional relevant articles. Table 1 and 2 presents a detailed summary of the included original studies. Of the 24 original research articles included in this literature review, 12 studies compared a natural environment with an urban city environment, 14 studies compared a natural environment with an indoor setting, and one survey study compared nature with a self-monitored control group. Two articles contained more than one experiment (Kerr et al., 2006; Mayer et al., 2009), with two and three experiments, respectively. The type of natural setting for experiments was varied, with six taking place in parks, eight on university campuses, seven in forests, three in nature reserves, two in arboretums and one in an allotment garden. The studies included 18 randomised experiments, while eight used a non-randomised design, and one study was a survey. The 24 original articles involved 2,017 adults, mean age 29.4 ± 13.4 years (five studies did not report age). Eight experiments were performed exclusively with males and six exclusively with females.

3.1 Previous literature reviews

Two systematic reviews have been published on the topic of comparative effects of physical activity in nature and indoor and urban environments. In 2010, Bowler et al. published a systematic review of the added health benefits of exposure to natural environments compared with built environments (i.e. urban and indoor). The review included 25 studies, 16 of which studied an emotional outcome, and four with cortisol as an outcome. The review found that activity in natural environments compared with built environments has beneficial effects in regards to reduced anger, fatigue and sadness. There was a less consistent effect on positive emotions. Similarly, there was little difference in the effects on cortisol between environmental settings. Another systematic review comparing the effects of physical activity in nature and indoor settings on mental and physical well-being included 11 studies and found that physical activity in nature is beneficial for mental well-being compared with the same activities indoors (Thompson Coon et al., 2011).

This literature review complements the work of Thompson et al. (2011) and Bowler et al. (2010). The review is of a newer date, and includes several studies not included in those reviews (Park et al., 2008; Mayer et al., 2009; Park et al., 2010; Roe & Aspinall, 2010; Johansson et al., 2011; Park et al., 2011; Van den Berg & Custers, 2011; Williams & Gill, 2011; Mao et al., 2012; Gatersleben & Andrews, 2013).

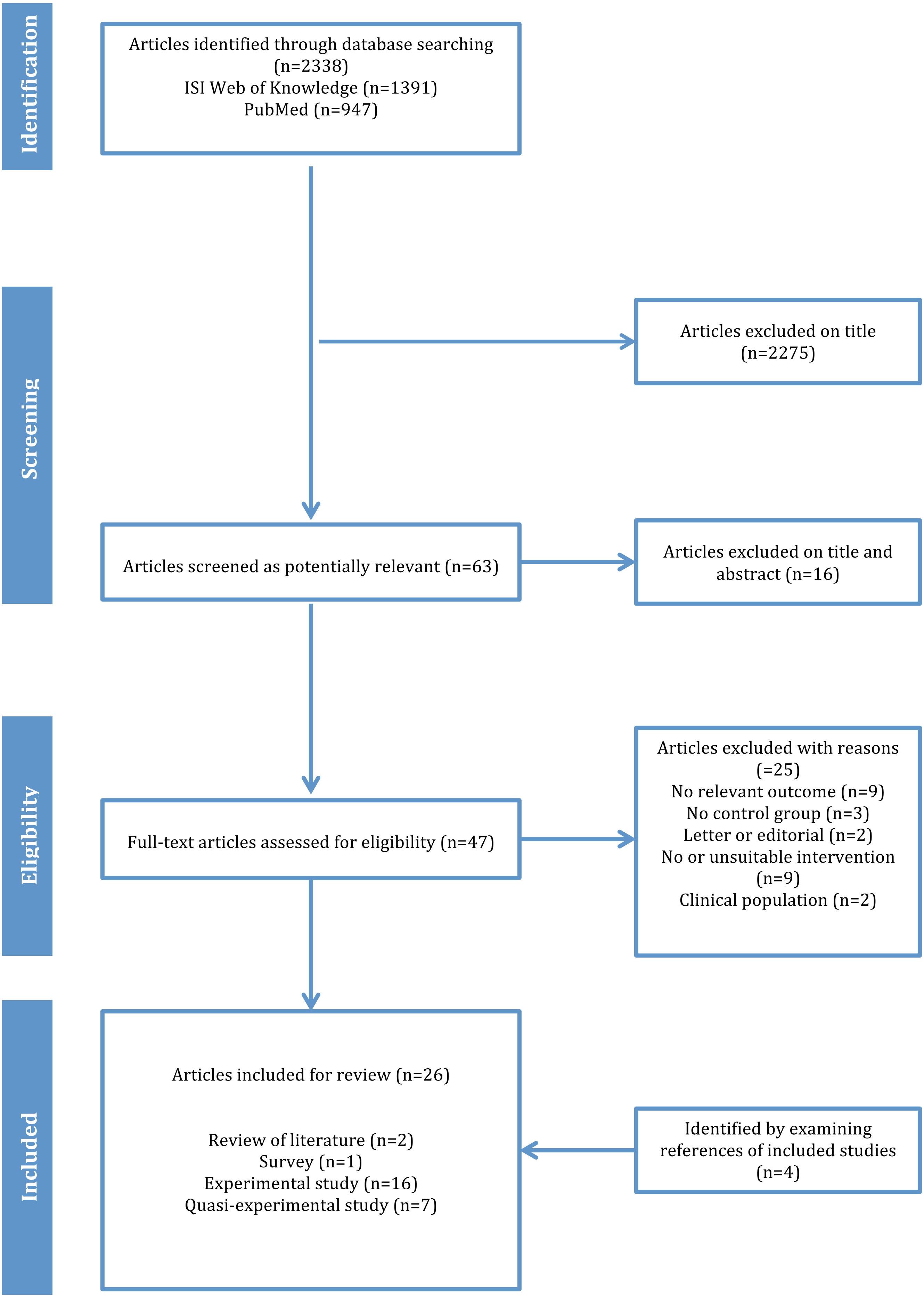

Figure 2: Flow chart of the literature search process. Adapted from the PRISMA flow diagram (PRISMA, n.d.).

3.2 Natural versus urban environments

In this section the results of green exercise versus urban environments are presented, divided by results on cortisol and emotions. Table 1 gives a summary of the included studies on natural versus urban environments. The studies are conducted in Sweden, USA, United Kingdom, Japan and China. Two studies examined the effects of running, while 11 studies investigated the effect of walking.

3.2.1 Effect of nature on cortisol

Moderate physical activity in nature, such as walking in a forest for 15–20 minutes, resulted in lower salivary cortisol levels compared with walking in an urban setting for groups of young Japanese and Chinese men (Tsunetsugu et al., 2007; Park et al., 2010; Mao et al., 2012). However, Park et al. (2007) failed to observe any difference between groups after walking in nature and a city environment. The natural setting for all studies was large broad-leafed forests outside major cities, while the urban settings was in downtown areas of cities.

3.2.2 Effect of nature on emotional responses

As demonstrated above, interacting with nature can influence a physiological stress response such as cortisol production; however, nature can also have an impact on emotional outcomes such as mood and affect.

Some studies administered a mentally fatiguing task prior to exposure to the environmental settings in order to assess the restorative properties of the environments on a mentally fatigued state in accordance with ART. Hartig et al. (2003) assigned participants to one of four study arms. The procedure consisted of an environmental treatment condition (natural or urban) and a pre-treatment task condition (task or no-task). Positive affect increased and anger decreased in the no-task group walking in nature, whereas the opposite was seen in the urban no-task group. A mentally fatiguing task prior to treatment was also used in Berman et al.'s (2008) study comparing walks in a park and a downtown city area. The group walking in the park experienced significantly greater positive affect than did the group walking in the city.

The majority of studies, however, did not mentally fatigue the participants prior to testing but rather examined how the environment affects psychological measures in the participants' natural state. Casually walking in forests is repeatedly seen to increase positive mood and decrease negative mood compared to walking in cities (Morita et al., 2007; Park et al., 2010; Park et al., 2011; Mao et al., 2012). Similarly, positive affect is significantly higher after a short 10-minute walk in a nature preserve than in a downtown area (Mayer et al., 2009) (experiment 1). Longer walks also contribute to improved mental well-being, as Roe and Aspinall (2010) found in their study, where members of a walking group walked in a park or a town centre for 1 hour, and higher positive affect was observed after the park walk than after the city walk. Johansson et al. (2011) sought to examine whether social context influences the psychological effects of walking in natural or urban environments. The participants walked in an urban park alone and with a friend, and along city streets alone and with a friend. Only the feeling of revitalisation was significantly higher after walking alone in the park than in the other conditions.

While walking in nature shows more promise in increasing mood and positive affect than urban settings do, the effects of running are less consistent. Research using experienced runners to examine the restorative effects of environments observed no difference in positive affect and mood between groups running in nature and those running in an urban setting (Bodin & Hartig, 2003; Butryn & Furts, 2003). However, mood improved in both studies from pre- to post-test, regardless of running condition.

Table 1: Detailed summary of studies on natural versus urban environments.

Author, Year, Country	Purpose	Design	n	Subject characteristics	Interventions	Duration	Outcomes	Main findings
Bodin & Hartig, 2003, Sweden	Examine the psychological effects of the environment during running	Randomised, open, crossover	12	Regular runners (50% female), mean age 39.7 years	1. Running in a park (14 km) 2. Running in an urban city area (14 km)	4 single visits on separate days	-Exercise-Induced Feeling Inventory -Negative Mood Scale	↓anxiety-depression ↓anger -from pre- to post run, regardless of running condition
Butryn & Furts, 2003, USA	Examine the relationship between psychological measures and exercise environment	Nonrandomised, open, counterbalanced crossover	30	Female distance runners, mean age 31 years	1. Running in a natural setting (park) (6.4 km) 2. Running in an urban setting (downtown area of a city) (6.4 km)	2 single visits on separate days	-Profile of Mood States -Exercise Induced Feeling Questionnaire	↓total mood disturbance ↑positive engagement ↑revitalization -from pre- to post run, regardless of running condition
Hartig et al., 2003, USA	Examine restoration in natural and urban settings	Randomized, open, parallel groups	112	Healthy students with normal BP, 50% female, mean age 20.8 years, 97% non-smokers	1. Walking in a nature reserve +task 2. Walking in urban setting +task 3. Walking in a nature reserve, no task 4. Walking in urban setting, no task	1 single visit 50 minutes	Zuckerman's Inventory of Personal Reactions	↑positive affect ↓anger -in nature reserve ↓positive affect ↑anger -in urban setting
Park et al., 2007, Japan	Examine physiological effects of "forest bathing"	Randomized, open, crossover	12	Healthy male students, mean age 22.8 years	1. Walking in a forest 2. Walking in a city	2 visits on separate days 20 minutes	Salivary cortisol	No significant difference between groups for cortisol

Morita et al., 2007, Japan	Examine psychological effects of “forest bathing” on a large number of participants	Survey	498	Healthy volunteers (244 male, 254 female), mean age 56.2 years	1. Walking in a forest for self-chosen duration (mean 2 hours 20 minutes) 2. Walking in any non-forest location for a self-chosen duration	2 single visits on separate days	Multiple Mood Scale-Short Form	↓hostility ↓depression ↑liveliness -after forest than control
Tsunetsugu et al., 2007, Japan	Examine physiological effects of “forest bathing”	Randomized, open, crossover	12	Male students, mean age 22 years	1. Walking in a forest 2. Walking in a city	2 visits on separate days 15 minutes	Salivary cortisol	↓ cortisol in forest than city after walking
Berman et al., 2008, USA	Examine the restorative effects of walking in nature and walking in an urban setting	Randomised, open, counterbalanced crossover	38	Healthy students (23 female, 15 male), mean age 22.6 years	1. Walking outdoors in a park 2. Walking in an urban downtown area	2 single visits on separate days 55 minutes	Positive and Negative Affect Schedule	↑positive affect after park than urban setting
Mayer et al., 2009, USA Experiment 1	Examine psychological benefits of exposure to nature	Randomised, open, parallel group	76	Students (51 females, 22 males, 3 unidentified), age not reported	1. Walking in a nature preserve 2. Walking in a city downtown area	1 single visit 10 minutes	Positive and Negative Affect Schedule	↑positive affect after walking in nature preserve than city
Park et al., 2010, Japan	Examine the physiological and psychological effects of viewing nature and walking in nature	Randomized, open, crossover	280	Healthy male students, mean age 21.7 years	1. Walking in a forest 2. Walking in an urban setting	2 single visits on separate days in 24 locations. 12 subjects per location 16±5 minutes	-Salivary cortisol -Profile of Mood States	↓ cortisol ↓tension ↓depression ↓anger ↓fatigue ↓confusion ↑vigour -after walking in forest than city

Roe & Aspinall, 2010, United Kingdom	Examine restorative effects of walking in rural or urban settings	Nonrandomized, open, crossover	11	Healthy participants, (4 males, 7 females) mean age 46 years,	1. Walking in a park 2. Walking in a town centre	2 single visits on separate days 1 hour	Mood Adjective Check List	↑ positive affect in rural group than urban group
Johansson et al., 2011, Sweden	Examine affective and cognitive effects of walking in an urban park or a street, and social context	Randomized, open, counterbalanced, crossover	20	Healthy men and women (50%), mean age 24.2 years	1. Walking in an urban park (alone) 2. Walking in city streets (alone) 3. Walking in urban park (with friend) 4. Walking in city streets (with friend)	4 single visits on separate days 20 minutes	Exercise-Induced Feeling Inventory Negative Mood Scale	↑ revitalization after walking in park alone than other three settings
Park et al., 2011, Japan	Examine psychological responses to forest and urban environmental settings and the physical characteristics of these environments	Randomized, open, crossover	168	Healthy male students, mean age 20.4 years	1. Walking in a forest 2. Walking in a city	2 visits on separate days in 14 locations. 12 subjects per location 15 minutes	Profile of Mood States	↓ tension ↓ anger ↓ fatigue ↓ confusion ↑ vigour ↓ total mood disturbance -after walking in forest than city
Mao et al., 2012, China	Examine the effects of walking in the forest on human health	Randomized, open, parallel groups	20	Healthy male students, 20.8 years	1. Walking in a forest 2. Walking in a city	1 single visit 1.5 hours x2	-Serum cortisol -Profile of Moods States	↓ cortisol ↓ tension ↓ depression ↓ anger ↓ fatigue ↓ confusion ↑ vigour -after walking in forest than a city

3.3 Natural versus indoor environments

In this section the results of green exercise versus indoor environments are presented, divided by results on cortisol and emotions. Table 2 gives a summary of the included studies on natural versus indoor environments. The studies are conducted in Australia, USA, United Kingdom, Japan and the Netherlands. Three studies examined the effects of running, ten studies investigates the effect on walking, and one the effects of gardening.

3.3.1 Effect of nature on cortisol

Vigorous exercise reduced cortisol in a study on the moderating effects of environments in male amateur triathlon and marathon runners (Harte & Eifert, 1995). In a counterbalanced crossover, the participants completed an outdoor run, indoor run with sounds of their own breathing, indoor run with typical outdoor sounds or seated reading. Running in the outdoor condition produced significantly lower urinary cortisol compared with running indoors while listening to the sounds of their own breathing. However, no difference was seen between running outdoors and running indoors with everyday “outdoor sounds”. Gardening was also found to reduce salivary cortisol in a study comparing gardening with reading indoors following a stress induction (Van den Berg & Custers, 2011). The stress induction significantly raised salivary cortisol levels from baseline, and while both gardening and reading lowered cortisol, the reduction was greater in the gardening group. Nonetheless, at post-activity measurement the difference was no longer significant. Similarly, no significant difference was observed in salivary cortisol in postmenopausal women after walking in a green campus area or on a treadmill in an exercise lab (Teas et al., 2007).

3.3.2 Effect of nature on emotional responses

Plante et al. have conducted a series of three studies on healthy students comparing walking in outdoor university campus environments with various indoor conditions (Plante et al., 2003; Plante et al., 2006; Plante et al., 2007). In 2003, students walked outdoors, indoors with a virtual reality video of the outdoor walk, and indoors without the video, or just viewed the video while seated (Plante et al., 2003). The outdoor walk elicited higher feelings of energy and lower feelings of tiredness than did the indoor walk, but only for females. The experiment was repeated in 2006 with only three study arms: an outdoor walk, indoor walk with a virtual reality video, or seated viewing of the video (Plante et al., 2006). Higher feelings of energy and lower feelings of calmness and tiredness were observed after walking outdoors than after walking or sitting indoors. In 2007, only female participants were used to examine the psychological benefits of exercise environments in a social context (Plante et al., 2007). The students were assigned to walk outdoors with a friend or alone, or walk indoors on a treadmill with a friend or alone. Higher energy and lower calmness and tiredness were experienced from pre- to post-test irrespective of walking condition; however, enjoyment was higher after the outdoor walks than after the indoor walks on a treadmill.

Examining affective responses after outdoor or indoor walks for postmenopausal women, Teas et al. (2007) found higher positive affect and lower negative affect after walking outdoors compared with walking on a treadmill in an exercise lab. Using a similar design, Focht (2009) observed higher positive affect for female students during outdoor walks than during indoor walks on a treadmill; however, after the walk the difference was no longer significant. Peacock et al. (2007) compared two contrasting everyday leisure activities, namely walking in a park and walking in an indoor shopping mall. They found that the participants had significantly lower negative mood after walking in the park than after walking in the shopping mall. However, Williams and Gill (2011) found no significant difference between young women walking on an indoor track and walking on an outdoor path, although the participants felt more energetic and less tired after the walk than before the walk regardless of condition.

In two separate experiments, Mayer et al. (2009) compared psychological responses in students walking in an arboretum versus watching videos of a nature walk and an urban walk in one experiment, and walking in an arboretum versus watching a video of a nature walk in another experiment. In both experiments they observed higher positive affect after walking in the arboretum than after watching the videos. In contrast, another study found that students taking walks in nature categorised as low prospect/high refuge or high refuge/low prospect or watching videos of the same walks, experienced higher positive affect after watching the videos of the walk than after actually walking (Gatersleben & Andrews, 2013). However, anger was lower in the outdoor walking group.

In addition to walking, one study showed that moderate activity such as gardening produced significantly higher positive affect after a stress induction than did reading indoors (Van den Berg & Custers, 2011). A correlation analysis revealed that changes in cortisol and positive affect were inversely related in the gardening group and directly related in the reading group.

In Harte and Eifert's (1995) study on male triathlon and marathon runners, they found lower feelings of tension, anger and fatigue and higher feeling of vigour after the outdoor run than after the indoor run with internal focus. In addition, the participants felt lower feelings of depression after the outdoor run than after all three other conditions. Kerr et al. (2006) compared running in nature and indoors in both recreational and competitive runners. Recreational runners experienced higher scores for pride after running in nature than after running in a laboratory. They also felt more relaxed and excited and less anxious and shameful after the run than before the run, but the difference between groups was not significant. Competitive runners felt less anxious and more excited after the run irrespective of running condition; however, feelings of tension and effort were higher after the outdoor run than after the indoor run.

Table 2: Detailed summary of studies on natural versus indoor environments.

Author, Year, Country	Purpose	Design	n	Subject characteristics	Interventions	Duration	Outcomes	Main findings
Harte & Eifert, 1995, Australia	Examine exercise-induced emotional and psycho-neuroendocrine change in different environmental settings	Nonrandomized, open, counterbalanced, crossover	10	Male amateur triathletes or marathon runners, mean age 27.1 years	1. Outdoor run 2. Indoor run with external focus (outdoor sounds) 3. Indoor run with internal focus (sounds of own breathing) 4. Reading in laboratory	Four single visits on separate days 45 minutes	-Profile of Mood States -Urinary cortisol	↓ tension ↓ anger ↓ fatigue ↑ vigour -after outdoor run than indoor internal run and control ↓depression after outdoor run than all three other conditions ↓cortisol after outdoor run than indoor internal run
Plante, 2003, USA	Examine the psychological benefits of aerobic exercise in outside and indoor settings	Randomized, open, parallel groups	154	Healthy students (52 men, 102 women), age not reported	1. Outdoor walk 2. Indoor walk on treadmill with virtual reality 3. Indoor walk on treadmill 4. Indoor seated viewing of virtual reality	1 single visit 20 minutes	Activation-Deactivation Adjective Check List	↑energy ↓tiredness -after outdoor walk than indoor, for females not males
Kerr et al., 2006, Japan, Experiment 1	Examine psychological effects of exercising in laboratory and natural exercise environments in recreational runners	Nonrandomised, open, counterbalanced crossover	22	Male recreational runners, mean age 22.7 years	1. Indoor run on treadmill in exercise laboratory (5 km) 2. Outdoor run in a natural environment (university campus) (5 km)	2 single visits on separate days	Tension and Effort Stress Inventory	↑relaxation ↑excitement ↓anxiety ↓shame -from pre to post-test regardless of condition ↑pride in outdoor run than indoor run

Kerr et al., 2006, Japan, Experiment 2	Examine psychological effects of exercising in laboratory and natural exercise environments in competitive runners	Nonrandomised, open, counterbalanced crossover	22	Male competitive runners, mean age 20.6 years	1. Indoor run on treadmill in exercise laboratory (5 km) 2. Outdoor run in a natural environment (5 km)	2 single visits on separate days	Tension and Effort Stress Inventory	↓anxiety ↑excitement -regardless of running condition ↑tension ↑effort -after outdoor run than indoor run
Plante et al., 2006, USA	Examine the psychological effects of exercise paired with virtual reality	Randomised, open, parallel groups	112	Healthy students (47 male, 65 female), age not reported	1. Outdoor walk in campus area 2. Indoor walk on treadmill while viewing video of campus walk 3. Just viewing the video of the campus walk	1 single visit 20 minutes	Activation-Deactivation Adjective Check List	↑energy after outdoor walk than viewing video ↓calmness after outdoor walk than indoor walk and viewing video ↓tiredness after outdoor walk than indoor walk
Peacock et al. 2007, United Kingdom	Examine the effect of walking outdoors on mental health and well-being	Nonrandomised, open, crossover	20	Volunteers (7 male, 13 female), age range: 31 to 70 years	1. Walking in a park 2. Walking in an indoor shopping mall	2 single visits on separate days 1 hour	Profile of Mood States	↓anger ↓confusion ↓depression ↓tension -in park than indoor shopping mall
Plante et al., 2007, USA, Experiment 2	Examine the psychological benefits of exercise environments	Randomized, open, parallel groups	88	Female students, mean age 19.3 years	1. Outdoor walk alone 2. Outdoor walk with friend 3. Indoor walk on treadmill alone 4. Indoor walk on treadmill with friend	1 single visit 20 minutes	Activation-Deactivation Adjective Check List	↑enjoyment after outdoor than indoor walk ↑energy ↓calmness ↓tiredness -from pre to post-test regardless of condition

Teas et al, 2007, USA	Examine the physiological and psychological effects of outdoor and indoor exercise	Nonrandomized, open, crossover	19	Postmenopausal women, non-smokers, mean age 58 years	1. Outdoor walk in campus area 2. Indoor walk on treadmill	2 single visits on separate days 1 hour	-Positive Affect Scale -Negative Affect Scale -Salivary cortisol	↑ pleased ↑ delighted ↓ worry ↓ frustration -after outdoor walk than indoor walk -No significant difference in cortisol between groups
Focht, 2009, USA	Examine effect of outdoor and indoor walks on affective responses, enjoyment, and intention to walk for exercise	Randomised, open, counterbalanced crossover	35	Healthy female students, mean age 22.1 years	1. Indoor walk on a treadmill 2. Outdoor walk on a university campus area	2 single visits on separate days 10 minutes	Exercise-Induced Feeling Inventory	↑revitalization ↑positive engagement -during outdoor than indoor, but not after
Mayer et al., 2009, USA Experiment 2	Examine psychological benefits of exposure to nature	Randomised, open, parallel group	92	Students (61 females, 28 males, 3 unidentified), age not reported	1. Walking in an arboretum 2. Watching a video of a nature walk 3. Watching a video of an urban walk	1 single visit 10 minutes	Positive and Negative Affect Schedule	↑positive affect after arboretum walk than both video conditions
Mayer et al., 2009, USA Experiment 3	Examine psychological benefits of exposure to nature	Randomised, open, parallel group	64	Students (29 males, 33 females, 2 unidentified), age not reported	1. Walking in an arboretum 2. Watching a video of a nature walk	1 single visit 10 minutes	Positive and Negative Affect Schedule	↑positive affect after arboretum walk than video
Van den Berg & Custers, 2011, Netherlands	Examine the stress relieving effects of gardening after stress induction	Randomized, open, parallel groups	30	Healthy allotment garden holders, 22 female, mean age 57.6 years	1. Outdoor gardening 2. Indoor reading	1 single visit 30 minutes	-Salivary cortisol -Positive and Negative Affect Schedule	↓ cortisol for both groups. Greater decrease in gardening group. No significant difference at post-activity ↑positive affect in gardening than reading group

Williams & Gill, 2011, USA	Examine the effects of outdoor and indoor exercise on affect attentional focus	Randomised, open, counterbalanced, parallel groups	26	Women, mean age 20.5 years	1. Walking on an indoor track 2. Walking on an outdoor path	2 single visits on separate days 30 minutes	Activation-Deactivation Adjective Check List	↑energy ↓tiredness -from pre to post-test regardless of condition
Gatersleben & Andrews, 2013, United Kingdom	Examine the effects of high prospect/low refuge and low prospect/high refuge natural environments on stress recovery and mental fatigue	Nonrandomised, open, parallel groups	34	Students (20 female), mean age 22 years	1. Walk in a high prospect/low refuge natural environment 2. Walk in a low prospect/high refuge natural environment 3. Viewing video of a high prospect/low refuge natural environment 4. Viewing video of a low prospect/high refuge natural environment	1 single visit 10 minutes	Zuckerman's Inventory of Personal Reactions	↑positive affect after viewing video than walking in nature ↓anger after walking in nature than viewing video

4.0 DISCUSSION

The majority of studies concerning cortisol compared walking in a forest with walking in a city. They employed similar experimental designs, and except for Park et al. (2007), all found significantly lower salivary cortisol concentration following exposure to nature than to an urban setting (Tsunetsugu et al., 2007; Park et al., 2010; Mao et al., 2012). However, the endocrine effects appeared to be relatively short-term, as Park et al. (2007) and Tsunetsugu et al. (2007) reported cortisol concentration levelling off between groups by the evening of the same day. Furthermore, it could be argued that the difference in salivary cortisol levels between participants in natural and urban environments was not due to a moderating effect of nature but rather a stimulating effect of the urban environment. The measurements for all studies were done in the morning, and as cortisol levels follow a consistent diurnal rhythm, declines in cortisol during the day are expected (Fries et al., 2009; Golden et al., 2011). Taking into consideration that noise can acutely raise cortisol levels (Kirschbaum & Hellhammer, 1999), it is possible that the noise from the urban walking sessions raised the participants' cortisol levels, while the reduction seen in the nature group was simply due to the normal decline.

To measure the endocrine response to exercise environment, Harte and Eifert (1995) used urinary cortisol. The authors noted that following vigorous exercise, urine is more concentrated compared with that of a subject who has been at rest, which could possibly account for the observed change in cortisol concentration. Regarding activity in an allotment garden versus reading, there was not a significant difference in salivary cortisol between the group gardening or reading indoors after the intervention (Van den Berg & Custers, 2011). This may be due to the difference in activity level between control and intervention group. It is possible a more pronounced difference could be evident if both groups held the same activity level.

At the time of writing, only a limited number of studies measuring cortisol were available, and all performed single measurements before and after intervention. They therefore did not take into account the circadian production of cortisol.

Furthermore, single measurements are shown to have very low between-visit reliability (Golden et al., 2011). Based on the reviewed studies no definite inference can be drawn regarding the effects of green exercise on cortisol. This is similar to the meta-analysis by Bowler et al. (2010), that found little difference in the effects of exercise environment on cortisol.

Contrary to the findings on cortisol concentration, there seems to be a general agreement of improvements in emotions after low-intensity green exercise such as walking or gardening, compared with an urban or indoor setting (Hartig et al., 2003; Plante et al., 2003; Plante et al., 2006; Peacock et al., 2007; Plante et al., 2007; Morita et al., 2007; Teas et al., 2007; Berman et al., 2008; Mayer et al., 2009; Park et al., 2010; Johansson et al., 2011; Park et al., 2011; Van den Berg & Custers, 2011; Mao et al., 2012). Some studies do demonstrate conflicting results, with no difference between intervention groups after the intervention (Focht, 2009; Williams & Gill, 2011; Gatersleben & Andrews, 2013). However, these studies still found beneficial effects with improvements during the intervention (Focht, 2009) and increased positive affect irrespective of intervention condition (Williams & Gill, 2011).

Studies on running in nature versus urban settings did not reveal a difference between settings, although improvements in mood were seen from pre- to post-run in female experienced runners (Bodin & Hartig, 2003; Butryn & Furts, 2003). This parallels the findings on male competitive runners running either in nature or indoors (Kerr et al., 2006). Irrespective of running condition, there was an improvement in mood. The outdoor setting more closely resembles an actual competitive situation, and could possibly explain why competitive runners had higher perceived tension and effort following the outdoor run than after the indoor run, while recreational runners did not.

Considering the reviewed results on emotions collectively, the notion that green exercise can offer more beneficial effects on mental health than can similar activity in urban or indoor settings seems to be well substantiated. It should be noted, though, that this applies to low to moderate activity, as high-intensity activities such as running showed less consistent results, with one study finding a difference in mood between groups (Harte & Eifert, 1995) and three studies showing no difference between groups (Bodin & Hartig, 2003; Butryn & Furts, 2003; Kerr et al., 2006). The findings are in line with expected results for affect and mood following physical activity at various intensities. A meta-analysis by Reed and Ones (2006) found that physical activity at low and moderate intensity elicited greater emotional responses than did high-intensity activity. It appears that as long as the activity is of low to moderate intensity, nature contributes to more positive emotions.

It is notable that walks of as short a duration as 10 to 20 minutes can significantly improve emotions more in nature than in urban and indoor settings. Similar findings on green exercise were reported by Barton & Pretty (Barton & Pretty, 2010). Their meta-analysis observed larger improvements in mood following 5-minute walks than 10-60 minute, half-day and full-day walks. This has practical applications when planning exercise interventions for previously sedentary individuals who may have barriers towards physical activity. In addition, if each bout were associated with positive emotions, it could help achieve higher adherence to an exercise regimen.

Narrative reviews are often associated with bias (Green et al., 2006), but a systematic approach in searching and selecting studies was used in order to attempt to increase objectivity while still retaining a narrative description of studies. This review contained several studies, not included in previous reviews on the subject (Bowler et al., 2010; Thompson Coon et al., 2011). This resulted in being able to differentiate between high and low intensity in the effects of green exercise on emotions, a finding these reviews did not report. However, the review is limited by its scope, including only cortisol and emotions as the reviewed outcomes. Another limitation is that a variety of outdoor settings were used, and not all studies examined the effects of nature but rather different environments in general on psychological responses to physical activity. Some of the study settings may therefore not include much green space or control for disturbing elements, such as traffic, people and pollution. All studies reviewed, apart from one survey, were experimental studies with crossover or parallel groups. A large variety of natural environments were tested, with mainly urban or indoor control groups. Since this review only included healthy adults, they are not representative of the general population. Thus, generalisation of the results to clinical or other populations cannot be made. Since most studies used volunteers, it is possible that there were cases of self-selection bias. Only studies with a control group were included in this review, although some control groups did not involve physical activity (Mayer et al., 2009, experiment 2 and 3; Van den Berg & Custers, 2011; Gatersleben & Andrews, 2013), which lowers the validity regarding the findings from those studies.

This literature review revealed several gaps that are addressed by the following experimental study. No previous studies have examined the long-term endocrine effects of green exercise. All cortisol measurements were taken immediately following the activity, but by measuring the cortisol awakening response in the morning after the exercise session, one can assess the carryover effect of restorative benefits to the following day. Furthermore, no previous research on green exercise has combined aerobic and strength training. Surprisingly, only one study from the literature review with cortisol as an outcome reported correlations between cortisol and emotional responses to green exercise (Van den Berg & Custers, 2011). However, both psychological and physiological responses were measured immediately after the intervention.

In sum, it appears green exercise of low intensity results in greater improvements in emotions compared with built environments, although no assumptions can be made regarding effects of green exercise on cortisol.

STUDY 2 – EXPERIMENT

The aim of the experimental study was to examine the effects of green exercise on the cortisol awakening response (CAR) in healthy working adults, as well as whether the CAR was inversely correlated with positive affect and tranquillity and directly correlated with negative affect and fatigue.

5.0 METHODS

5.1 Dataset and design

The dataset used for this master's thesis is the result of a pilot study conducted in the city of Alta in Finnmark, Norway, in 2012. The main researcher was Giovanna Calogiuri, along with colleagues from the Section for Public Health Sciences, Department of Landscape Architecture and Spatial Planning at NMBU – Norwegian University of Life Sciences (Camilla M. Ihlebæk, Grete G. Patil, Ruth Kjærsti Raanaas and Katinka H. Evensen), and UiT – the Artic University of Norway (Andi Weydahl and Sajia Mikkala).

The pilot study was a controlled randomised trial with two parallel groups: physical activity in nature (green exercise) and physical activity indoors (Calogiuri, 2013). In the week prior to the intervention, baseline measurements were performed during sedentary activity indoors. The intervention consisted of two physical activity sessions, 1 day apart. Ten weeks later the participants were contacted for some follow-up questions; however, this information is not used for this thesis. A methodological discussion is presented in subchapter 7.1.

5.2 Participants

The study sample consisted of 14 (seven male and seven female) sedentary or moderately fit healthy adults (Calogiuri, 2013). Employees at Finnmark University College and Alta Municipality were recruited. The participants were randomly allocated to either the indoor or outdoor activity group. However, to ensure balance in the two groups, the randomisation was stratified by age, gender and physical activity level. The groups were fairly similar in terms of demographic, anthropometric and fitness status measures. Table 3 shows the demographic, anthropometric and fitness measures of the participants in the nature and indoor exercise groups. In addition, the groups were similar concerning smoking (with one smoker, one ex-smoker, and five non-smokers in each group) and education. Details of the recruitment and randomisation process are described elsewhere (Calogiuri, 2013). All subjects signed an informed consent after being made aware of the benefits and risks involved in participating in the research project. The Norwegian Social Science Data Service approved the research study on July 13th 2012 (project number 30906).

Table 3: Demographic, anthropometric and fitness measurements of the participants in the nature and indoor exercise groups.

	Group	
Parameter	Nature	Indoor
Gender (M/F)	4/3	3/4
Age (years)	50.4±7.8	48±8.7
BMI (Kg/m^2)	24.6±2.2	25.8±2.7
Height (m)	1.71±0.08	1.72±0.09
Weight (kg)	72.6±11.9	76.1±10.6
Max heart rate (bpm)	174.4±20.4	180.4±9.9
Physical activity (hours/week)	5.0±2.7	7.9±5.6
VO_{2max} (L/Min)	39.2±4.7	40.4±10.4

Note: Continuous variables are means ± standard deviation

5.3 Baseline and exercise intervention

The intervention was part of a seminar on the theoretical fundaments and practical guidelines for planning and maintaining an exercise program (Calogiuri, 2013). Baseline measurements were taken after a preliminary meeting where no activity was performed. The physical activity sessions were part of two workshops the following week. The exercise intervention consisted of a biking session (25 minutes) and a resistance training session using elastic rubber bands with handles (20 minutes). After an initial warm-up, the participants were asked to maintain a moderately high intensity (14–16 on the Borg scale) during the biking session, as indicated by the Borg scale (Borg, 1982). The indoor group used bikes from Spinning® Fitness, while the outdoor group used their own bikes (Calogiuri, 2013). The resistance training session included eight exercises covering all major muscle groups (legs, upper and lower back, shoulders, arms, chest and abdominals). Men used elastic bands with hard resistance, and women used bands with medium resistance. Experienced instructors led the physical activity sessions.

5.4 Environmental settings

A traditional "gym setting" was reproduced for the indoor environment (Calogiuri, 2013). Figure 3 shows the environmental settings where the exercise was executed (the track used for the outdoor biking session is not shown).
In the indoor setting, there was no visual contact with nature, the room was well lit by artificial light in addition to natural light from windows covered by white

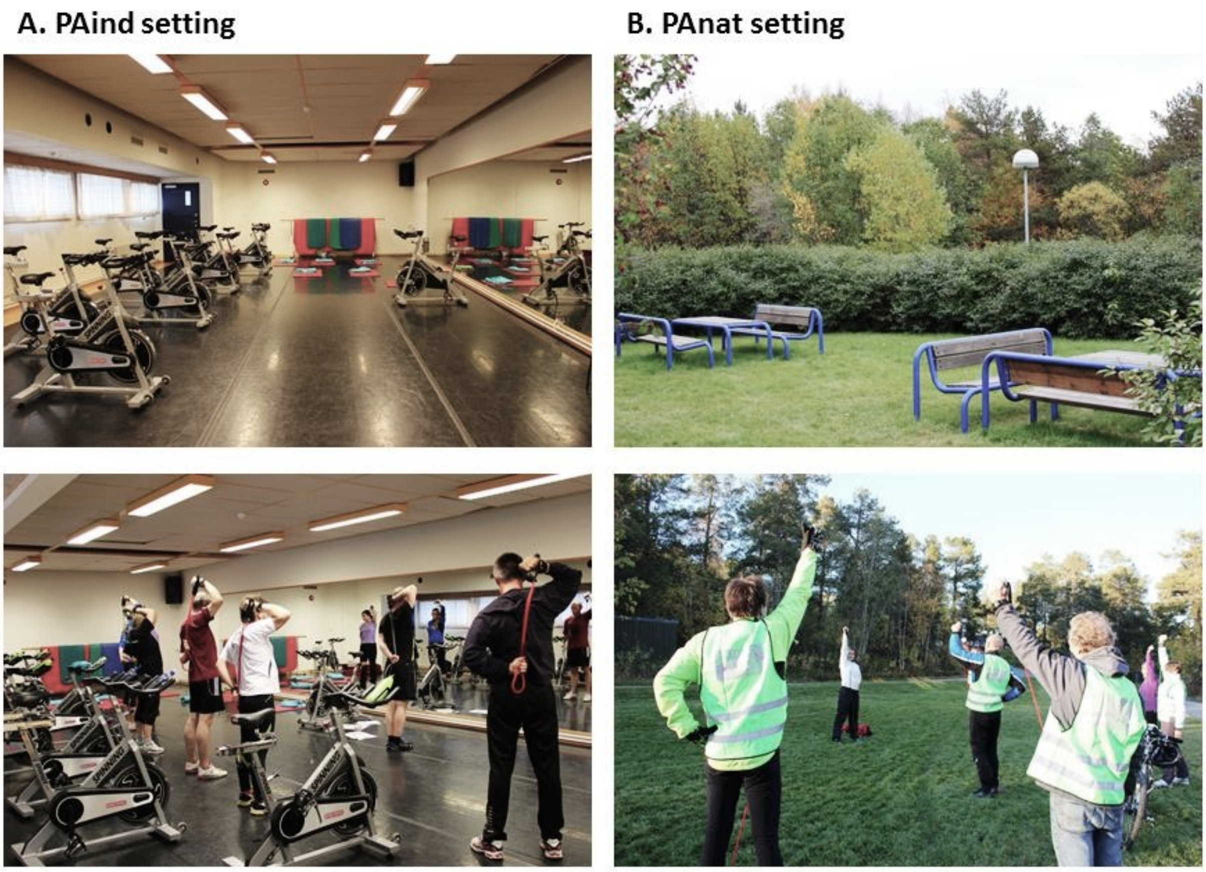

Figure 3: Environmental settings for the physical activity interventions. PAind: "Traditional" gym environment. PAnat: Natural setting in a park. Image reproduced from (Calogiuri, 2013) with permission from author.

curtains, and large mirrors enhanced space and light perception. There was no exposure to external air, but a ventilation system ventilated the room. The nature group biked on a track in a forest area that was located near the college. Small trees surrounded the track. The strength training session was performed in a yard enclosed by high bushes and overlooking the forest area. The weather conditions were good, with temperatures around 8–10 °C outside, and 20°C indoors, with 60% air humidity.

5.5 Main outcome measures

Salivary cortisol

As a marker of HPA axis activity, the participants took self-administered saliva samples on the mornings following each physical activity session (Calogiuri, 2013). Three samples were obtained each morning: immediately upon awakening, 15 minutes after awakening and 30 minutes after awakening. These three measurements were used to determine the cortisol awakening response and area under the curve. Calculation of area under the curve is described in greater detail below. Saliva samples were obtained by chewing on a cotton swab (Salivette, Sarstedt, Numbrecht, Germany) for the duration of 1 minute (Calogiuri, 2013). All saliva samples were frozen, and later thawed for analysis. The samples were preliminary centrifuged at 1000g for 15 minutes, and analysed by electrochemiluminescence immunoassay (ECLIA), using Roche E 170 module (Roche, Basel, Switzerland). The laboratory analyses were performed at the Hormone Lab (Oslo University Hospital HF, Aker Hospital, Norway).

Physical Activity Affect States

The Physical Activity Affect States (PAAS) scale (Lox et al., 2000), translated to Norwegian by faculty at NMBU, was used to measure self-reported exercise-induced affective states (Calogiuri, 2013). The PAAS was used to investigate possible associations with the CAR. The instrument consists of four subscales – *positive affect*, *negative affect*, *fatigue* and *tranquillity* – with each subscale containing three items (Lox et al., 2000). The subscales consist of the following

12 items, measured on a 5-point Likert scale from 0 ("do not feel") to 4 ("feel very strongly"):

- **Positive affect**: upbeat, energetic and enthusiastic
- **Negative affect**: miserable, discouraged and crummy
- **Fatigue**: tired, worn-out and fatigued
- **Tranquillity**: calm, peaceful and relaxed

To ensure the groups were balanced, socio-demographic (gender, age, marital status, education, smoking use, occupation status), anthropometric (weight, height, BMI), and fitness and health status measures (maximum heart rate, hours of physical activity per week, VO_{2max}, diseases) were obtained (Calogiuri, 2013). The amount of physical activity the participants engaged in during their free time per week was assessed using Godin's Leisure Time Exercise Questionnaire (Godin & Shephard, 1985). The questionnaire differentiates between different physical activity intensities: strenuous (high heart rate), moderate (not exhaustive) and light (minimal effort). Examples of activities are provided for each intensity level. Ratings of perceived exertion were measured using the Borg Scale of Perceived Exertion (Borg, 1982), and used to instruct the participants of the intensity they should keep during the exercise (Calogiuri, 2013). The scale ranges from 6 (complete rest) to 20 (maximal exertion) (Borg, 1982). A range of additional measures was obtained in the study; however, these are not used as variables for this thesis. A full description of measures from the study is given elsewhere (Calogiuri, 2013).

5.6 Intervention procedure

Prior to the intervention, subjects completed a preliminary questionnaire including socio-demographic information and the PAAS (Calogiuri, 2013). The physical activity sessions took place immediately after the subjects' working day. Intake of coffee and nicotine was restricted on the days of the interventions. After meeting at 3:00 pm, the participants underwent the exercise sessions in their respective environments.

Baseline PAAS was completed at the initial meeting and before and after each exercise session (Calogiuri, 2013). The morning after each meeting, the participants took saliva samples upon awakening and 15 and 30 minutes after awakening to ascertain the cortisol awakening response. The participants were asked to refrain from any physical activity other than that of the intervention.

5.7 Data cleaning

Visual inspection of the raw data, as well as visual inspection of a box plot, was performed prior to analysis. One subject was found to have an abnormally high awakening level for salivary cortisol on one of the mornings after the exercise sessions. After consulting the research literature on normal values for the CAR (Aardal & Holm, 1995; Laudat et al., 1988; Kirschbaum & Hellhammer, 2000; Wüst et al., 2000), it was concluded that the measurement was most likely due to error. The measurement was replaced with a value one unit larger than the next highest score in the distribution, as suggested by Tabachnick and Fidell (1996).

5.8 Calculation of area under the curve

Area under the curve for the CAR was not part of the original dataset and was calculated specifically for this thesis. Computation of the area under the curve (AUC) is a widely used method to summarise information that is contained in repeated measures over time, such as with the cortisol awakening response (Pruessner et al., 2003). In data with repeated measures, each observation contains two types of information: intensity (distance from the ground) and change over given time (distance from neighbouring measurement) (Fekedulegn et al., 2007). The AUC takes advantage of both pieces of information and simplifies statistical analysis by converting multivariate data to univariate data, as well as increasing the power of the statistical testing (Fekedulegn et al., 2007; Pruessner et al., 2003).

Area under the curve with respect to the ground (AUC_G) and *area under the curve with respect to increase* (AUC_I) were calculated in Microsoft Excel for Mac (version 14.0) using the trapezoidal formula presented by Pruessner et al.

(2003).[1] Figure 4 shows a graphical representation of the CAR with three measurements at 15-minute intervals.

$$AUC_G = \frac{(m_2 + m_1)\times t_1}{2} + \frac{(m_3 + m_2)\times t_2}{2}$$

In the formula for AUC_G, m_1 to m_3 represent the three cortisol measurements, and t_1 and t_2 signify the time between measurements (in this case, time between measurements was 15 minutes). Salivary cortisol was measured at three time points: upon awakening and at 15-minute intervals to 30 minutes after awakening.[2] AUC_G conveys information on the difference between the single measurements and the distance from zero, i.e. the ground. It is associated with total hormonal output (Pruessner et al., 2003).

$$AUC_I = AUC_G - m_1 \times \sum_{i=1}^{n-1} t_i$$

The formula for AUC_I is based on AUC_G but removes the area between the ground and m_1 for all time points, with m_1 being the first measure (awakening) and t_i the time between measurements.[3] AUC_I is associated with change over time (i.e. the increase or decrease from awakening) (Pruessner et al., 2003). AUC_G and AUC_I are both used in the analysis, as they supply different information concerning the cortisol awakening response (i.e. total hormonal output and change from awakening, respectively).

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[1] The formula for AUC_G has been shortened from its original six measurements to three measurements.
[2] An example of calculation of AUC_G using data from one subject: ([15.9 + 11.5] x 15) / 2 + ([18.2 + 15.9] x 15) / 2 = 461.25.
[3] An example of calculation of AUC_I using data from one subject: AUC_G – 11.5 x (15 + 15) = 116.25.

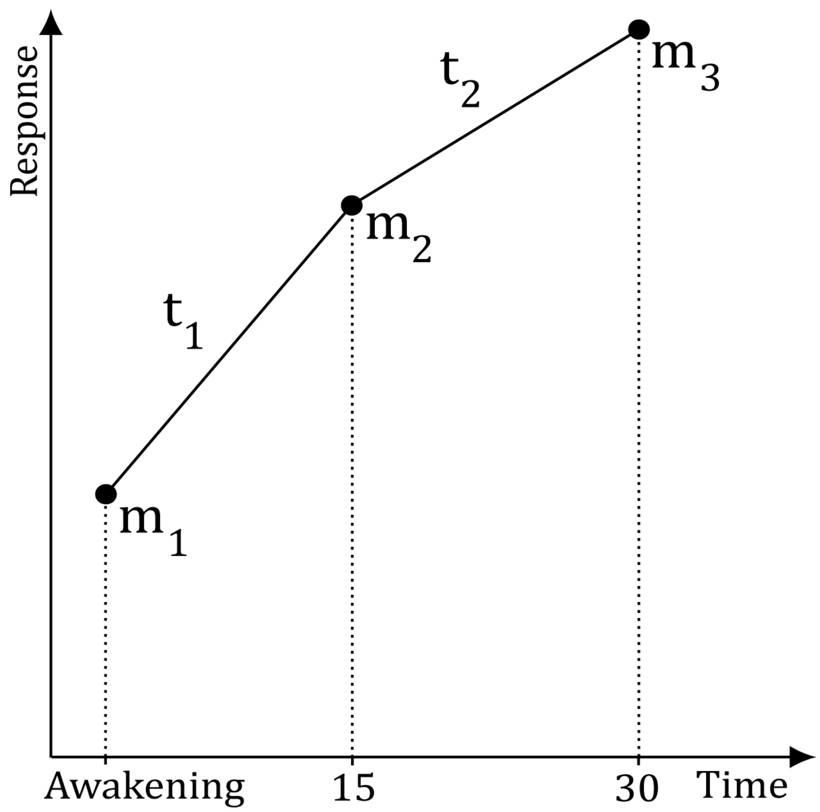

Figure 4: Illustration of the cortisol awakening response with three measurements 15 minutes apart. Adapted from Fekedulegn et al. (2007).

5.9 Data analysis

Prior to analysis, the variables were checked to see whether they violated the assumptions associated with analysis of covariance and Pearson product-moment correlation (Pallant, 2011). Shapiro–Wilk's test of normality was used to check the data for normality, and Levene's test of equality of error variances was used to check for homogeneity of variance. Linear relationships between the dependent variables and covariates were scrutinised using a scatter plot, while the homogeneity of regression slopes was tested statistically with ANCOVA. Statistical analysis was performed using SPSS for Mac (versions 20.0 and 21.0). The means of the AUC values after the two physical activity interventions were used as dependent variables, with intervention group as the independent variable. The means of the AUC values were used as suggested by Clow et al. (2010) because errors can occur due to the sampling being self-administered in the participants' home setting. The mean of the PAAS was subsequently used in order for it to be comparable to the AUC. Two-way mixed intraclass correlation

(ICC) was calculated between the two sessions for all variables used in the analysis.

One-way between-subjects analysis of covariance (ANCOVA) was employed to compare the effect of physical activity between groups on the area under the curve of the cortisol awakening response. AUC_G and AUC_I baseline values were used as covariates to control for differences between the groups that may have existed prior to the experiments. Pearson correlation was used to examine the relationship between the cortisol awakening response and subscales of the PAAS.

6.0 RESULTS

In this chapter the results from the experimental study are introduced. First the effect of green exercise on the CAR is presented, followed by associations between exercise-induced affect and the CAR.

6.1 Effect of green exercise on the cortisol awakening response

Preliminary checks of assumptions for normality, linearity, homogeneity of variance, and homogeneity of the regression slopes showed that none of the assumptions were violated. Intraclass correlation analysis showed that the ICC for physical activity sessions 1 and 2 were excellent for AUC_G (ICC = 0.9, $p < 0.001$). However, for AUC_I the intraclass correlation was non-significant (ICC = 0.527, $p = 0.067$).

Figure 5 shows the slope of the CAR (mean of the two exercise sessions). From the graph it is evident that the green exercise group had higher awakening levels with a small, steady decline. The CAR for the indoor exercise group had lower awakening levels, but with a steep incline over the next 30 minutes.

One-way between-group ANCOVA revealed that after controlling for pre-intervention AUC_G values, there was no significant difference for mean AUC_G between outdoor and indoor physical activity ($F(1, 11) = 0.527$, $p = 0.483$, η_p^2 =

0.046). However, there was a significant difference between groups for mean AUC_I after controlling for pre-intervention AUC_I value ($F(1, 11) = 8.425$, $p = 0.014$, $\eta_p^2 = 0.434$). The partial eta-squared signifies the proportion of the variance of the AUC that is explained by the exercise condition (Pallant, 2011).

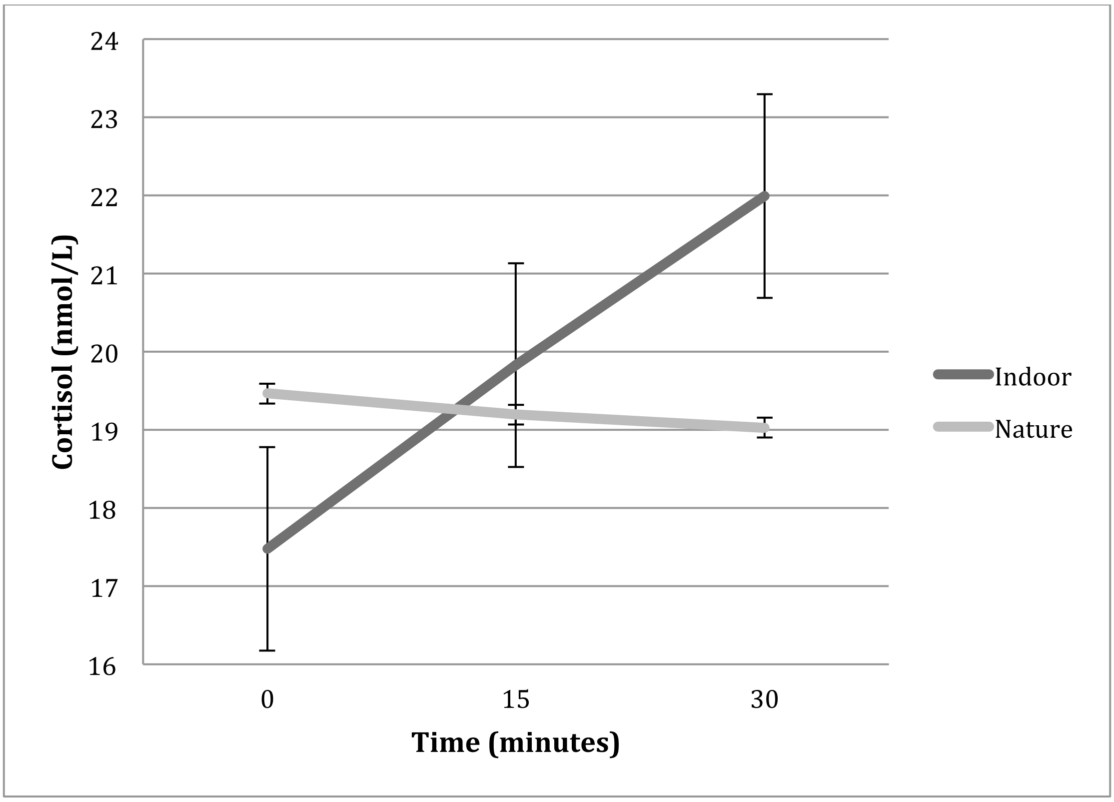

Figure 5: Cortisol awakening response for 14 subjects in natural and indoor exercise groups at awakening (0), and subsequently +15 and +30 minutes past awakening. Cortisol values are mean of two physical activity sessions on separate days. Error bars represent standard error.

6.2 Relationship between exercise-induced affect and cortisol awakening response

Negative affect was excluded from the analysis due to a large number of missing values. Normality analysis revealed that *fatigue* did not meet the assumptions of normality and was subsequently excluded from the analysis. ICC for *positive affect* and *tranquillity* were 0.872 ($p < 0.001$) and 0.649 ($p = 0.037$), respectively. Table 5 presents Pearson correlation coefficients between AUC for the cortisol awakening response and positive affect and tranquillity. Only tranquillity and AUC_G for both groups combined reached statistical significance (r=0.671, p<0.01). While no other correlations reached statistical significance, there was a trend of strong direct correlation between AUC_G and tranquillity in both the indoor and nature group separately. In addition, a similar weak correlation was observed between AUC_I and positive affect for both the indoor and nature group.

Table 4: Pearson correlation between area under the curve for the cortisol awakening response, positive affect and tranquillity from Physical Activity Affect Scale. AUC_G: Area under the curve with respect to the ground, AUC_I: Area under the curve with respect to increase.

	Both groups (n=14)		Indoor (n=7)		Nature (n=7)	
	AUC_G	AUC_I	AUC_G	AUC_I	AUC_G	AUC_I
Positive affect	.236	-.084	.749	.233	-.221	.287
Tranquility	.671*	.112	.714	.067	.629	.202

* Correlation is significant at the 0.01 level (2-tailed).

7.0 DISCUSSION

In this chapter the results will be discussed, followed by a methodological discussion. The aim of the experimental study was to examine the effects of green exercise on the CAR in healthy working adults, and whether the CAR was related to exercise-induced affective states. The results showed no significant difference for AUC_G between groups, but a moderate significant difference was observed for AUC_I. The only significant correlation between CAR and affective responses was between AUC_G and tranquillity for the overall sample.

The non-significant difference in AUC_G between groups indicates that total hormonal output was not affected by green exercise. The similarity between groups for total cortisol output is likely due to the higher awakening levels of cortisol in the nature group. From Figure 5 it is clear that the awakening levels were higher in the nature group, thereby causing the AUC_G to be larger. While the awakening levels in the indoors group was lower than the nature group, there was a steady incline, whereas the CAR for the nature group remained fairly flat. This is reflected in the difference in AUC_I.

The CAR for the nature group did not show a typical pattern of increase during the first 30 minutes (Figure 5). In this study the awakening value of cortisol was higher for the nature group than for the indoor group in addition to lower AUC_I. Clow et al. (2010) states that if both the awakening value and AUC_I are affected it implies a general effect on the HPA axis.

The subjects rated their affective states using the PAAS after each exercise session. A study using the same dataset this thesis is based on reports significantly higher positive affect in the nature group following the physical activity sessions than in the indoor group when adjusted for baseline values (Calogiuri et al., in press). Contrary to the hypothesis for research question 3 – that the CAR is inversely associated with exercise-induced positive affect and tranquillity – no significant relationships were observed for the nature or indoor group (fatigue and negative affect were excluded from the analysis, and no relationship with the CAR could be ascertained) (Table 4). This might suggest that psychological and physiological responses to green exercise have separate mechanisms. However, this seems unlikely, considering that previous research has found inverse associations between positive psychological states and the CAR (Chida & Steptoe, 2009) and that the psycho-evolutionary theory postulates that the mechanism for nature's stress-reducing capabilities is through increased positive affect (Ulrich et al., 1991). Another explanation might be that affective responses to exercise have been shown to return to baseline values within 30 to 120 minutes (Carron et al., 2003; Reed & Ones, 2006). Considering that the CAR was measured more than 12 hours after the affective responses were measured, a potential relationship between the variables most likely dissipated during this time frame. Ulrich et al. (1991) also failed to find any relationship between affective states and physiological indicators of stress in their landmark study from 1991, claiming temporal incongruence as a possible reason.

Another possibility is that the lack of a significant relationship is due to type II error. It is probable that there is a relationship – although the sample is too small to determine significance – as AUC_I is positively associated with positive affect for both the nature and indoor group, while AUC_G is inversely correlated with positive affect in the nature group and strongly correlated in the indoor group (although not significant). This suggests that there is wide variation in the data material and the sample is too small to clearly identify a pattern.

The strong significant correlation between tranquillity and AUC_G for the overall sample is surprising (Table 4). This means that the more tranquil the participants felt after the exercise regardless of exercise condition, the higher the total cortisol output was the following day. In addition, tranquillity was also positively correlated with AUC_I in the overall sample, and with AUC_G and AUC_I in both the nature and indoor group. In an attempt to explain this peculiar finding, a search regarding studies on the relationship between tranquillity and cortisol was conducted, although no studies could be located. Since this is the first study utilising these measures together, future research could clarify whether the positive relationship between the CAR and tranquillity is genuine or due to the small sample.

The findings from the experimental study show that the AUC_I for the cortisol awakening response was significantly lower in the green exercise group than the indoor exercise group. Indicating a possible effect of nature on the HPA axis. What may have caused this difference in AUC_I for the CAR between groups?

It appears the indoor environment lacks something found in the natural setting that leads to an effect on the cortisol awakening response. According to the psycho-evolutionary theory (Ulrich et al., 1991), the features present in nature such as vegetation, spatial openness and presence of pattern or structure can elicit faster recovery from stress than does interacting with built environments. In unthreatening natural environments, these features can appear aesthetically pleasing, and signal survival and welfare, and cause an increase in positive affect and change in physiological responses. The subjects in this study did not undergo a stress induction prior to the intervention. They did, nonetheless, perform the exercise sessions after a normal working day, which one can assume involves a moderate amount of stress. Furthermore, vigorous exercise itself is stressful, and the release of stress hormones in conjunction with physical activity is similar to that of an acute psychological stress reaction (Jonsdottir & Ursin, 2008).

Regarding positive affect, the psycho-evolutionary theory is supported by the findings from Calogiuri et al. (in press). This study further corroborates the theory by adding findings of an attenuated CAR (as indicated by lower AUC_I) after green exercise, indicating a lower stress burden. However, whether affect is related to the CAR is unclear based on the present data.

7.1 Methodological discussion

To the best of my knowledge, this is the first study examining the neuroendocrine effects of green exercise from a "medium-term" perspective. The CAR is amongst the most reliable indicators of HPA axis activation (Golden et al., 2011), and measuring the CAR after exposure to natural environments allows for an assessment of possible longer-term effects of a reduced stress response than does only measuring cortisol directly after the intervention. In addition, it takes into account the circadian fluctuation of cortisol production, unlike all previous studies on the subject. As previously mentioned, AUC_I gives an indication of the dynamic change in cortisol after awakening (Clow et al., 2010). It is therefore more informative in elucidating the pattern in post-awakening cortisol secretion than is AUC_G. However, including both AUC_G and AUC_I is important as it allows for assessment of both the total output of the CAR and the change after awakening. It should be noted that even though the AUC is the recommended unit of analysis (Clow et al., 2010), there is some chance additional information could be revealed by analysing the CAR using *repeated measures ANOVA*.

The thesis is based on a pilot study with limited budget, and therefore a small sample size. The purpose of pilot studies is to determine whether the study design and procedure are feasible (Skovlund & Bretthauer, 2007). As this was the first time some of these outcome measures were used in this type of study, a pilot study was warranted. Another possible weakness is that the resistance portion of the nature intervention took place outside the university area where some of the participants worked. This may have influenced the feeling of "being away”, which Kaplan’s (1995) attention restoration theory gives as one of the factors involved in restorative mechanisms of nature.

7.1.1 Design

An intervention study evaluates the effect of intervening (e.g. a treatment) in someone’s life (Klepp, 2007). The purpose of an intervention study is to measure the effect of an intervention on one or more outcomes, with a randomised controlled trial being the best way to ascertain whether there is a causal link between intervention and outcome (Skovlund & Bretthauer, 2007). The experimental study was a randomised control trial; therefore a causal relationship might be ascertained assuming the validity of the results is rigorous.

7.1.2 Internal validity

The internal validity of an experiment concerns the degree to which one can establish that the observed effect is caused by the intervention (Klepp, 2007). As previously noted, the dataset is based on a pilot study with a small sample size. The small sample size is a major limitation of the study. No power analysis was performed to estimate the sample size needed (Calogiuri, 2013). In order to establish whether the effects of the intervention are valid, the intervention group and control group need to be fairly similar in terms of demographic variables (Skovlund & Bretthauer, 2007). Because of the small sample size in this study, the randomisation was stratified by gender and age (Calogiuri, 2013), thereby safeguarding against unbalanced groups (Klepp, 2007). This increases the internal validity. The participants were informed about the structure of the experiment beforehand and were told they would be randomly allocated to a green exercise or indoor exercise group (Calogiuri, 2013). While blinding is difficult in intervention studies, care was taken in this study to avert problems stemming from this by not disclosing the hypothesis of the study to the participants. However, the participants might have figured out the purpose of the study by knowing the measurements that were taken. This does to an extent reduce the internal validity of the results. In addition, there is a chance the participants became more aware of nature during the period in which the intervention took place.

Regarding the outlier, it was decided that the data from the participant with the outlier be kept due to the small size of the sample, albeit altered to a less extreme value. This is in line with suggestions by Tabachnick and Fidell (1996). Nonetheless, AUC_I is sensitive to errors, as they are amplified (Pruessner et al., 2003). AUC_I tends to accumulate errors of the first measure (m_1). Given that the formula is based on the difference between the awakening value and the following measures, if the first measure contains an error, AUC_I will also contain the error. This may have caused inaccuracies in AUC_I and could be a threat to the internal validity. It might also be the reason for the non-significant result of the intraclass correlation between AUC_I for the two exercise sessions. AUC_G is not affected by the first measure to same degree.

In this thesis the CAR from two separate sampling days was used, as suggested by Clow et al. (2004). This allows for consideration of day-to-day consistency, analysed by intraclass correlation. However, as many as six days of measurements has been suggested to achieve reliable measures (Hellhammer et al., 2007).

7.1.3 External validity

External validity is concerned with the generalisability of the results, that is, whether the results are valid for populations other than the one studied (Skog, 2010). The study sample was well balanced in terms of demographic and health-related variables for healthy employees, with a mean age of 49 ± 8 years, both sedentary and moderately active individuals, all with mainly office-based work. It could therefore be argued that the sample reflects the target population of healthy workers. However, due to the small sample size, the generalisability of the results is very limited.

The CAR was determined from saliva samples taken upon awakening by the participants in their home setting (Clow et al., 2010). This gives ecological validity but simultaneously introduces uncertainty as to whether the sampling procedure was adhered to. Ecological validity refers to whether one can generalise from behaviour observed during the study to behaviour in the natural setting (Schmuckler, 2001).

8.0 OVERALL DISCUSSION

In this chapter the implications of the findings are discussed in light of relevance to public health. The literature review demonstrated that low intensity green exercise can lead to greater improvements in emotions than in urban or indoor environments, but that the effects are inconclusive when it comes to higher intensity exercise. Results were also inconclusive for the impact of green exercise on cortisol. By measuring cortisol, a biomarker for allostatic load, the experimental study indicates lower allostatic load following green exercise as compared to indoor exercise.

8.1 Reduced allostatic load and public health implications

Increasingly, threats to human health cannot be explained by diseases and genetic factors, but relate to the more sedentary and stressful lifestyle of the modern world (Nilsson et al., 2011). Stress is the result of an interaction between the brain and the body (McEwen, 2006). The release of chemical mediators such as cortisol enables the supply of energy to the organs in the body where it is needed. However, chronic elevation of stress hormones can result in "wear and tear" on the body, for example through chronically elevated blood pressure. Considering the allostatic load of everyday work-related stress allows for a more expansive perspective on the application of restorative environments in the improvement of public health (Hartig, 2004). From an evolutionary perspective, the sustained physiological and psychological arousal associated with obtaining food, water and shelter and avoiding predators would likely have led to diseases related to allostatic overload, such as cardiovascular disease (Ulrich et al., 1991). Allowing recuperation from stress prevents accumulation of physiological damage to the body, such as the HPA axis and the cardiovascular system. The lower stress burden following green exercise is not likely to have a dramatic health effect in the short term. However, there may be a cumulative effect on long-term outcomes, such as improvements in health (Hartig, 2004).

Over time, reduced allostatic load as a result of green exercise may prevent ill health related to allostatic overload.

8.2 Preservation of nature as upstream health promotion

Roughly 80% of the Norwegian population lives in urban areas (Miljødirektoratet, 2012), and most of the urban population has access to recreational green space (Ommundsen & Aadland, 2009; Miljødirektoratet, 2012). At the same time, as much as 83% of the Norwegian population fails to meet the recommendation of 30 minutes of daily moderate physical activity (Ommundsen & Aadland, 2009). A survey of users of Norwegian urban forests finds that the forests are mainly used for physical activity and as a retreat from the stresses of everyday life (Gundersen, 2009). Being able to reach nature from home was highly valued, and many of the respondents were concerned about the reduction of natural areas in their community. In Sweden, Grahn and Stigsdotter (2003) found that the closer green spaces were to people's homes, the more frequently they visited. Furthermore, they observed that the more time people spent in urban green space, the less they were affected by perceived stress, and that people preferred easy direct access. This shows the importance of having natural areas for physical activity in the local community. Furthermore, the significance of preserving nature where we live lies in the added benefits of interacting with our "original" habitat. We as humans originate from nature, and this is reflected in the way we turn to nature when we feel distressed. This may be because, as Ulrich claims in his psycho-evolutionary theory, we have yet to adapt to the built environments we occupy (Ulrich et al., 1991).

Conserving natural environments in dense urban areas should be a priority in management and planning in all sectors. Parliamentary Report no. 39 acknowledges spending time in nature as means to achieve a higher quality of life and states that one of the goals is for outdoor recreation (*friluftsliv*) to be freely available to the entire population as a health-promoting activity in nature and the local community (Miljøverndepartementet, 2001). In addition, preserving nature, as it is considered to contribute to the promotion of public health, is a national environmental aim (Miljøverndepartementet, 2013). In line with the Ottawa Charter (WHO, 1986), the government has decreed that it is the responsibility of the municipality to ensure that residents have access to opportunities for physical activity and nature experiences (Helsedepartementet, 2003). However, there currently is rapid densification of urban areas, and only 20–30% of urban green space from the 1950s remain (Miljødirektoratet, 2012). This has a negative impact on biodiversity, play and physical activity areas, and pedestrians' transport possibilities (Miljøverndepartementet, 2002; Miljødirektoratet, 2012).

From a health-promotion perspective, conserving green areas within cities and highlighting the benefits of engaging in nature can be an upstream approach to increasing the health of the population. Having access to nature, especially in close proximity to one's work or home, may be a facilitative setting for physical activity and stress reduction. This may prevent future disease trajectories in high-risk groups, thereby alleviating the pressure on the health system. This has major implications not only for public health but also for society as a whole. A population that is more physical fit and emotionally satisfied is less of a strain on the economy (Pretty et al., 2003).

8.3 Practical implications

Some workplaces are located near urban green spaces. In these instances, employers could recommend that employees take short walks if the job situation permits (Barton & Pretty, 2010). Many workplaces in Norway have exercise arrangements (Ommundsen & Aadland, 2009), and short walks in urban natural areas could be part of a company exercise arrangement.

Regardless of the setting, physical activity is beneficial to mental and physical health (Henriksson & Sundberg, 2008), and consistent physical activity leads to lower physiological strain from psychosocial stressors through increased efficiency of the HPA axis (Jonsdottir & Ursin, 2008). The recommendation for physical activity for adults is a minimum of 150 minutes of moderate-intensity activity or 75 minutes of high-intensity activity per week (Helsedirektoratet, 2014). Exercises that increase muscular strength of large muscle groups should be performed at least twice a week. Exercise equipment could therefore be placed in urban green spaces, such as urban parks and forests, allowing for free and accessible strength training. Furthermore, maintaining and creating new walking and jogging routes in nature could increase the amount of physical activity in the population. This could be part of intersectoral strategies, combining health promotion efforts with urban planning, primary health care, environmental management and social services, in order to maximise the use of nature as an exercise setting (Maller et al., 2005)

9.0 CONCLUDING REMARKS

This thesis has demonstrated a novel way of measuring and analysing the effect of green exercise. Using the cortisol awakening response has the advantage over using single measures taken immediately after the intervention because it takes into account the circadian rhythm of cortisol, increases the reliability of the cortisol measurements (Golden et al., 2011), and allows for an assessment of effects in the medium- to long-term. Using the area under curve further strengthens the examination of effects by ascertaining both total hormonal output and the increase after awakening (Pruessner et al., 2003; Clow et al., 2010).

The literature review found basis to claim that low intensity green exercise can lead to greater improvements in emotions compared to urban or indoor settings. Such a claim is not warranted for improvements in cortisol due to inconclusive results. The results from the experimental study imply that green exercise has a greater effect on the HPA axis than that of indoor exercise, as evident by a significantly lower AUC_I for the cortisol awakening response. The exercise-induced affective states did not correlate with the CAR as predicted. A statistically significant association was observed between AUC_G and tranquillity, although it was in the opposite direction of what hypothesised. It is therefore still unclear if the change in CAR is related to affective responses to green exercise.

Hypothesis 1 – that the cortisol awakening response is lower after green exercise than after similar exercise indoors – is strengthened based on the findings. Hypothesis 2 – that the cortisol awakening response is inversely associated with exercise-induced positive affect and tranquillity – can be rejected based on the findings. Due to exclusion of negative affect and fatigue, no statement regarding these variables can be made. However, there is a chance of committing a type I and type II error for hypothesis 1 and 2 respectively, considering the small sample size.

In conclusion, the findings from this thesis collectively suggest that green exercise is beneficial for emotional states, and may lead to lower stress burden. However, due to uncertainty regarding the internal validity of the results, only a tentative conclusion of greater stress reduction following green exercise can be made.

9.1 Future studies

More research is needed on the effects of green exercise on the CAR. Several recommendations are presented to ensure rigour in future research. Firstly, future studies should include an adequately large sample based on power analyses. Secondly, no monitoring of the participants' compliance to sampling time was conducted in this study. Smyth et al. (2013) found that delays greater than 15 minutes between awakening and start of saliva sampling leads to erroneous estimation of the CAR. The adherence to sampling time could be monitored using actigraphy equipment. Thirdly, In line with suggestions by Clow et al. (2004) and Hellhammer et al. (2007), the CAR should be estimated from saliva samples from several days to consider day-to-day consistency. Six days of sampling is recommended, with 2 days as a minimum. Finally, the association between affect and the CAR should also be studied further. Unfortunately, two of four PAAS subscales (negative affect and fatigue) were excluded from the analysis in this study due to poor normality. Future studies could likely avoid this with larger samples. Special focus should be kept on the association between tranquillity and the CAR based on the findings in this study.

10.0 REFERENCES

Aardal, E., & Holm, A.-C. (1995). Cortisol in Saliva —Reference Ranges and Relation to Cortisol in Serum. *European journal of clinical chemistry and clinical biochemistry , 33*, 927-932.

Butryn, T. M., & Furts, D. M. (2003). The effects of park and urban settings on the moods and cognitive strategies of female runners. *Journal of Sport Behavior , 26* (4).

Barton, J., & Pretty, J. (2010). What is the Best Dose of Nature and Green Exercise for improving Mental Health? A Multi-Study Analysis. *Environmental Scince & Technology , 44* (10), 3947-3955.

Beil, K., & Hanes, D. (2013). The Influence of Urban Natural and Built Environments on Physiological and Psychological Measures of Stress - A Pilot Study. *International Journal of Environmental Research and Public Health , 10*, 1250-1267.

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The Cognitive Benefits of Interacting With Nature. *Psychological Science , 19* (12), 1207-1212.

Biddle, S. J., & Mutrie, N. (2008). *Psychology of Physical Activity - Determinants, well-being and interventions* (2 ed.). New York: Routledge .

Bjørndal, A., & Hofoss, D. (2010). *Statistikk for helse- og sosialfagene* (2 ed.). Oslo: Gyldendal Akademisk.

Bodin, M., & Hartig, T. (2003). Does the outdoor environment matter for psychological restoration gained through running? *Psychology of Sport and Exercise , 4*, 141-153.

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine and science in sports and exercise , 14* (5), 377-381.

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BioMed Central Public Health , 10*, 456.

Calogiuri, G. (2013). *Trening ute eller inne? Rapport fra et prosjekt med datainnsamling under Forskningsdagene 2012.* Institutt for idretts- og realfag. Høgskolen i Finnmark.

Calogiuri, G., Evensen, K., Weydahl, A., Andersson, K., Patil, G., Ihlebæk, C., et al. (in press). Green exercise as a workplace intervention to reduce job stress. Results from a pilot study. *WORK: A Journal of Prevention, Assessment & Rehabilitation*.

Carron, A. V., Hausenblas, H. A., & Estabrooks, P. A. (2003). *The Psychology of Physical Activity.* New York: Mcgraw-Hill Higher Education.

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical Activity, Exercise, and Physical Fitness: Definitions and Distinctions for Health-Related Research. *Public Health Reports , 100* (2), 126-131.

Chida, Y., & Steptoe, A. (2009). Cortisol awakening response and psychosocial factors: A systematic review and meta-analysis. *Biological Psychology , 80*, 265–278.

Clow, A., Hucklebridge, F., & Thorn, L. (2010). The Cortisol Awakening Response in Context. *International Review of Neurobiology , 93*, 153-175.

Clow, A., Thorn, L., Evans, P., & Hucklebridge, F. (2004). The Awakening Cortisol Response: Methodological Issues and Significance . *Stress , 7* (1), 29-37.

Dockray, S., & Steptoe, A. (2010). Positive affect and psychobiological processes. *Neuroscience & Biobehavioral Reviews , 35* (1), 69-75.

Fekedulegn, D. B., Andrew, M. E., Burchfiel, C. M., Violanti, J. M., Hartley, T. A., Charles, L. E., et al. (2007). Area Under the Curve and Other Summary Indicators of Repeated Waking Cortisol Measurements. *Psychosomatic Medicine , 69*, 651-659.

Focht, B. C. (2009). Brief Walks in Outdoor and Laboratory Environments: Effects on Affective Responses, Enjoyment, and Intentions to Walk for Exercise. *Research Quarterly for Exercise and Sport , 80* (3), 611-620.

Frumkin, H. (2001). Beyond Toxicity - Human Health and the Natural Environment. *American Journal of Preventive Medicine , 20* (3), 234-240.

Fries, E., Dettenborn, L., & Kirschbaum, C. (2009). The cortisol awakening response (CAR): Facts and future directions. *International Journal of Psychophysiology , 72*, 67-73.

Gundersen, V. (2009). *Livet mellom trærne - en beskrivelse av forholdet mellom menneske og skog.* Ås: Norsk institutt for skog og landskap.

Gatersleben, B., & Andrews, M. (2013). When walking in nature is not restorative - The role of prospect and refuge. *Health & Place , 20*, 91-101.
Godin, G., & Shephard, R. J. (1985). A simple method to assess exercise behavior in the community. *Canadian Journal of Applied Sport Sciences , 10* (3), 141-146.
Golden, S. H., Wand, G. S., Malhotra, S., Kamel, I., & Horton, K. (2011). Reliability of hypothalamic-pituitary-adrenal axis assessment methods for use in population-based studies. *European Journal of Epidemiology , 26* (7), 511-525.
Grahn, P., & Stigsdotter, U. A. (2003). Landscape planning and stress. *Urban Forestry & Urban Greening , 2* (1), 1-18.
Green, B. N., Johnson, C. D., & Adams, A. (2006). Writing narrative literature reviews for peer-reviewed journals: Secrets of the trade. *Journal of Chiropractic Medicine , 5* (3), 101-117.
Hansmann, R., Hug, S.-M., & Seeland, K. (2007). Restoration and stress relief through physical activities in forests and parks. *Urban Forestry & Urban Greening , 6*, 213–225.
Harvey, R., & Ferrier, D. (2008). *Lippincott's Illustrated Reviews: Biochemistry* (5. Utgave ed.). Wolters Kluwer - Lippincott Williams & Wilkins.
Harte, J. L., & Eifert, G. H. (1995). The effects of running, environment, and attentional focus on athletes' catecholamine and cortisol levels and mood. *Psychophysiology , 32*, 49-54.
Hartig, T. (2004). Toward Understanding the Restorative Environment as a Health Resource. *Open Space: People Space. Engaging with the Environment. Conference Proceedings.* Edinburgh: OPENspace Research Centre.
Hartig, T., van den Berg, A. E., Hagerhall, C. M., Tomalak, M., Bauer, N., Hansmann, R., et al. (2011). Health Benefits of Nature Experience: Psychological, Social and Cultural Processes. In K. Nilsson, M. Sangster, C. Gallis, T. Hartig, S. de Vries, K. Seeland, et al., *Forests, Trees and Human Health* (pp. 127-168). Dordrecht: Springer.
Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology , 23*, 109-123.
Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, Nature and the Environment . (2004). *Nature and Health. The*

influence of nature on social, psychological and physical well-being . The Hague: Health Council of the Netherlands and RMNO .

Hellhammer, J., Fries, E., Schweisthal, O. W., Schlotz, W., Stone, A. A., & Hagemann, D. (2007). Several daily measurements are necessary to reliably assess the cortisol rise after awakening: State- and trait components . *Psychoneuroendrocrinology , 32*, 80-86.

Helsedepartementet. (2003). *St.meld. nr. 16 (2002-2003): Resept for et sunnere Norge - Folkehelsepolitikken.* Helsedepartementet, Oslo.

Helsedirektoratet. (2014). *Anbefalinger om kosthold, ernæring og fysisk aktivitet.* Oslo: Helsedirektoratet.

Henriksson, J., & Sundberg, C. (2008). Generelle effekter av fysisk aktivitet. In R. Bahr (Ed.), *Aktivitetshåndboken - Fysisk aktivitet i forebygging og behandling.* Oslo: Helsedirektoratet.

Johansson, M., Hartig, T., & Staats, H. (2011). Psychological Benefits of Walking: Moderation by Company and Outdoor Environment. *Applied Psychology: Health and Well-Being , 3* (3), 261-280.

Jonsdottir, I. H., & Ursin, H. (2008). Stress. In R. Bahr (Ed.), *Aktivitetshåndboken - Fysisk aktivitet i forebygging og behandling* (pp. 602-607). Oslo: Helsedirektoratet.

Juster, R.-P., McEwen, B. S., & Lupien, S. J. (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neuroscience and Biobehavioral Reviews , 35*, 2-16.

Kaplan, S. (1995). The Restorative Benefits of Nature: Toward an Integrative Framework. *Journal of Environmental Psychology , 15*, 169-182.

Kerr, J. H., Fujiyama, H., Sugano, A., Okamura, T., Chang, M., & Onouha, F. (2006). Psychological responses to exercising in laboratory and natural environments. *Psychology of Sport and Exercise , 7*, 345-359.

Kirschbaum, C., & Hellhammer, D. H. (1999). Noise and stress - salivary cortisol as a non-invasive measure of allostatic load. *Noise Health , 1*, 57-65.

Kirschbaum, C., & Hellhammer, D. H. (2000). Salivary Cortisol. *Encyclopedia of Stress , 3*, 279-383.

Kirschbaum, C., & Hellhammer, D. H. (1989). Salivary Cortisol in Psychobiological Research: An Overview. *Neuropsychobiology , 22*, 150-169.

Klepp, K.-I. (2007). Intervensjon i grupper. In P. Laake, A. Hjartåker, D. S. Thelle, & M. B. Veierød (Eds.), *Epidemiologiske og kliniske forskningsmetoder.* Oslo: Gyldendal Akademisk.

Laudat, M. H., Cerdas, S., Fournier, C., Guiban, D., Guilhaume, B., & Luton, J. P. (1988). Salivary Cortisol Measurement: A Practical Approach to Assess Pituitary-Adrenal Function . *Journal of Clinical Endocrinology and Metabolism , 66* (2).

Lox, C. L., Jackson, S., Tuholski, S. W., Wasley, D., & Treasure, D. C. (2000). Revisiting the Measurement of Exercise-Induced Feeling States: The Physical Activity Affect Scale (PAAS). *Measurement in Physical Education and Exercise Science , 4* (2), 79-95.

Lovallo, W. R. (2010). Emotions and Stress. In J. M. Suls, K. W. Davidson, & R. M. Kaplan (Eds.), *Handbook of Health Psychology and Behavioral Medicine.* Guilford Press.

Lovejoy, D. A. (2005). *Neuroendocrinology: An Integrated Approach.* Chichester: John Wiley & Sons, Ltd.

Mayer, S. F., Frantz, C. M., Bruelman-Senecal, E., & Dolliver, K. (2009). Why Is Nature Beneficial?: The Role of Connectedness to Nature. *Environment and Behaviour , 41* (5), 607-643.

Maller, C., Townsend, M., Pryor, A., Brown, P., & Leger, L. S. (2005). Healthy nature healthy people: "conatct with nature" as an upstream health promotion intervention for populations. *Health Promotion International , 21* (1), 45-54.

Mao, G., Lan, X., Cao, Y., Chen, Z., He, Z., Lv, Y., et al. (2012). Effects of Short-Term Forest bathing on Human Health in Broad-Leaved Evergreen Forest in Zhejiang Province, China. *Biomedical and Environmental Sciences , 25* (3), 317-324.

McEwen, B. S. (2006). Protective and damaging effects of stress mediators: central role of the brain . *Dialogues in Clinical Neuroscience , 8* (4), 367-381.

McEwen, B. S., & Seeman, T. (1999). Protective and Damaging Effects of Mediators of Stress - Elaborating and testing the concepts of allostasis and allostatic load. *Annals New York Academy of Science , 896*, 30-47.

McEwen, B. S., & Stellar, E. (1993). Stress and the Individual - Mechanisms Leading to Disease. *Archives of Internal Medicine , 153*, 2093-2101.

Miljøverndepartementet. (2013). *Prop. 1S (2013–2014) Proposisjon til Stortinget.* Miljøverndepartementet, Oslo.

Miljøverndepartementet. (2002). *St.meld. nr. 23 (2001-2002) - Bedre miljø i byer og tettsteder.* Miljøverndepartementet.
Miljøverndepartementet. (2001). *St.meld. nr. 39 (2000-2001): Friluftsliv - Ein veg til høgare livskvalitet*. Retrieved April 10, 2014, from http://www.regjeringen.no/nn/dep/kld/dokument/proposisjonar-og-meldingar/stortingsmeldingar/20002001/stmeld-nr-39-2000-2001-.html?id=194963
Miljødirektoratet. (2012, 04 17). *Grønnstruktur*. Retrieved 04 20, 2014, from http://www.miljostatus.no/Tema/Friluftsliv/Friluftsomrader/Gronnstruktur/
Mitchell, R. (2013). Is physical activity in natural environments better for mental health than physical activity in other environments? *Social Science & Medicine , 91*, 130-134.
Morita, E., Fukuda, S., Nagano, J., Hamajima, N., Yamamoto, H., Iwai, Y., et al. (2007). Psychological effects of forest environments on healthy adults: Shinrin-yoku (forest-air bathing, walking) as a possible method of stress reduction. *Public Health , 121*, 54-63.
Nilsson, K., Sangster, M., & Konijnendijk, C. C. (2011). Forests, Trees and Human Health and Well-being: Introduction. In K. Nilsson, M. Sangster, C. Gallis, S. Vries, K. Seeland, J. Schipperijn, et al. (Eds.), *Forests, Trees and Human Health.* New York: Springer.
Ommundsen, Y., & Aadland, A. A. (2009). *Fysisk inaktive voksne i Norge: Hvem er inaktive – og hva motiverer til økt fysisk aktivitet?* Helsedirektoratet; Den norske kreftforening; Norges Bedriftsidrettsforbund . Oslo: Helsedirektoratet; Den norske kreftforening; Norges Bedriftsidrettsforbund .
Pallant, J. (2011). *SPSS Survival Manual* (4th ed.). Crows Nest: Allen & Unwin.
Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T., & Miyazaki, Y. (2010). The physiological effects of Shinrin-Yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventive Medicine , 15*, 18-26.
Park, B.-J., Furuya, K., Kasetani, T., Takayama, N., Kagawa, T., & Miyazaki, Y. (2011). Relationship between psychological responses and physical environments in forest settings. *Landscape and Urban Planning , 102*, 24-32.

Park, B.-J., Tsunetsugu, Y., Kasetani, T., Hirano, H., Kagawa, T., Sato, M., et al. (2007). Physiological Effects of Shinrin-yoku (Taking in the Atmosphere of the Forest) - Using Salivary Cortisol and Cerebral Activity as Indicators. *Journal of Physiological Anthropology , 26*, 123-128.

Peacock, J., Hine, R., & Pretty, J. (2007). *The mental health benefits of green exercise activities and green care.* Centre for Environment and Society, Department of Biological Sciences. Colchester: Mind.

Penedo, F. J., & Dahn, J. R. (2008). Exercise and well-being: a review of mental and physical health benefits associated with physical activity. *Current Opinion in Psychiatry , 18*, 189–193 .

Petruzello, S. J., Landers, D. M., Hatfield, B. D., Kubitz, K. A., & Salazar, W. (1991). A Meta-Analysis on the Anxiety-Reducing Effects of Acute and Chronic Exercise - Outcomes and Mechanisms . *Sports Medicine , 11* (3), 143-182.

Plante, T. G., Aldridge, A., Su, D., Bogdan, R., Belo, M., & Kahn, K. (2003). Does Virtual Reality Enhance the Management of Stress When Paired With Exercise? An Exploratory Study. *International Journal of Stress Management , 10* (3), 203-216.

Plante, T. G., Cage, C., Clements, S., & Stover, A. (2006). Psychological Benefits of Exercise Paired With Virtual Reality: Outdoor Exercise Energizes Wheras Indoor Virtual Exercise Relaxes. *International Journal of Stress Management , 13* (1), 108-117.

Plante, T. G., Gores, C., Brecht, C., Carrow, J., Imbs, A., & Willemsen, E. (2007). Does Exercise Environment Enhance the Psychological Benefits of Exercise for Women. *International Journal of Stress Management , 14* (1), 88-98.

Popper, K. (2005). *The Logic of Scientific Discovery* (2 ed.). Routledge.

Pressman, S. D., & Cohen, S. (2005). Does Positive Affect Influence Health? *Psychological Bulletin , 131* (6), 925–971 .

Pretty, J., Griffin, M., Sellens, M., & Pretty, C. (2003). *Green Exercise: Complementary Roles of Nature, Exercise and Diet in Physical and Emotional Well-Being and Implications for Public Health Policy.* Centre for Environment and Society. Essex: University of Essex .

PRISMA. (n.d.). *PRISMA - Transparent Reporting of Systematic Reviews and Meta-Analyses*. Retrieved January 4, 2014, from http://www.prisma-statement.org/statement.htm

Pruessner, J. C., Kirschbaum, C., Meinlschmid, G., & Hellhammer, D. H. (2003). Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. *Psychoneuroendocrinology , 28*, 916-931.

Reed, J., & Ones, D. S. (2006). The effect of acute aerobic exercise on positive activated affect: A meta-analysis. *Psychology of Sport and Exercise , 7*, 477-514.

Roe, J. J., Ward Thompson, C., Aspinall, P. A., Brewer, M. J., Duff, E. I., Miller, D., et al. (2013). Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban Communities. *International Journal of Environmental Research and Public Health , 10*, 4086-4103 .

Roe, J., & Aspinall, P. (2010). The restorative benefits of walking in urban and rural settings in adults with good and poor mental health . *Health & Place , 17*, 103-113.

Salmon, P. (2001). Effects of physical exercise on anxiety, depression, and sensitivity to stress: a unifying theory. *Clinical Psychology Review , 21* (1), 33-61.

Schlotz, W., Hellhammer, J., Schulz, P., & Stone, A. A. (2004). Perceived Work Overload and Chronic Worrying Predict Weekend–Weekday Differences in the Cortisol Awakening Response. *Psychosomatic Medicine , 66*, 207–214 .

Schmuckler, M. A. (2001). What Is Ecological Validity? A Dimensional Analysis. *INFANCY , 2* (4), 419–436.

Skovlund, E., & Bretthauer, M. (2007). Kliniske studier. In P. Laake, A. Hjartåker, D. S. Thelle, & M. B. Veierød (Eds.), *Epidemiologiske og kliniske forskningsmetoder.* Oslo: Gyldendal Akademisk.

Skog, O.-J. (2010). *Å forklare sosiale sammenhenger - En regresjonsbasert tilnærming* (2 ed.). Oslo: Gyldendal Akademisk.

Smyth, N., Clow, A., Thorn, L., Hucklebridge, F., & Evans, P. (2013). Delays of 5—15 min between awakening and the start of saliva sampling matter in assessment of the cortisol awakening response. *Psychoneuroendocrinology , 38*, 1476—1483 .

Steptoe, A., Wardle, J., & Marmot, M. (2005). Positive affect and health-related neuroendocrine, cardiovascular, and inflammatory processes. *Proceedings of the National Academy of Sciences , 102* (18), 6508–6512.
Sterling, P., & Eyer, J. (1988). Allostasis: A New Paradigm to Explain Arousal Pathology. In S. Fisher, & J. Reason (Eds.), *Handbook of Life Stress, Cognition and Health* (pp. 629-649). Oxford: John Wiley & Sons Ltd.
Tabachnick, B. G., & Fidell, L. S. (1996). *Using Multivariate Statistics* (3 ed.). New York: Harper Collins.
Teas, J., Hurley, T., Ghumare, S., & Ogoussan, K. (2007). Walking Outside Improves Mood for Healthy Postmenopausal Women. *Clinical Medicine: Oncology , 1*, 35-43.
Tennant, C. (2001). Work-related stress and depressive disorders. *Journal of Psychosomatic Research , 51*, 697–704.
Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J., & Depledge, M. H. (2011). Does Participating in Physical Activity in Outdoor Natural Environments Have a Greater Effect on Physical and Mental Wellbeing than Physical Activity Indoors? A Systematic Review. *Environmental Science & Technology , 45* (5), 1761-1772.
Townsend, M., & Weerasuriya, R. (2010). *Beyond Blue to Green: The benefits of contact with nature for mental health and well-being.* Beyond Blue Limited: Melbourne, Australia.
Tsunetsugu, Y., Park, B.-J., Ishii, H., Hirano, H., Kagawa, T., & Miyazaki, Y. (2007). Physiological Effects of Shinrin-yoku (Taking in the Atmosphere of the Forest) in an Old-Growth Broadleaf Forest in Yamagata Prefecture, Japan. *Journal of Physiological Anthropology , 26*, 135-142.
Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress Recovery During Exposures to Natural and Urban Environments. *Journal of Environmental Psychology , 11*, 201-230.
Vaagbø, O. (1993). *Den norske turkulturen.* FRIFO.
Van den Berg, A. E., & Custers, M. H. (2011). Gardening Promotes Neuroendocrine and Affective Restoration from Stress. *Journal of Health Psychology , 16* (1), 3-11.

Van den Berg, A., Maas, J., Verheij, R. A., & Groenewegen , P. P. (2010). Green space as a buffer between stressful life events and health. *Social Science and Medicine , 70* (8), 1203–1210.

Williams, A. L., & Gill, D. (2011). Perceived Environmental Restorativeness and Affective Responses to Indoor vs. Outdoor Exercise. *Journal of Sport & Exercise Psychology* , 194-195.

Wilson, E. O. (1984). *Biophilia: the human bond with other species .* Cambridge: Harvard University Press.

WHO. (2009). *Global health risks: mortality and burden of disease attributable to selected major risks. .* World Health Organization.

WHO. (2008). *Intersectoral action*. Retrieved April 17, 2014, from Social determinants of health: http://www.who.int/social_determinants/thecommission/countrywork/within/isa/en/

WHO. (1986). Ottawa Charter for Health Promotion. *First International Conference on Health Promotion.* Ottawa: World Health Organization.

WHO. (1946). *Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference.* World Health Organization. New York: World Health Organization.

Wüst, S., wolf, J., Hellhammer, D. H., Federenko, I., Schommer, N., & Kirschbaum, C. (2000). The cortisol awakening response - normal values and confounds. *Noise & Health , 7*, 77-85.

Wüst, S., Federenko, I., Hellhammer, D. H., & Kirschbaum, C. (2000). Genetic factors, perceived chronic stress, and the free cortisol response to awakening . *Psychoneuroendocrinology , 25*, 707-720.

Yerrell, P. (2008). *National Evaluation of BTCV's Green Gym .* School of Health and Social Care Oxford Brookes University .

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