Exercise as intervention to reduce burnout

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CHAPTER 1

GENERAL INTRODUCTION

Work-related fatigue, exhaustion and burnout

Fatigue is commonly reported in the working population. It is a complex phenomenon referring to changes in motivation, emotion, behavior and information processing. Generally, it can be described as "a subjective feeling of having a reduced capacity to complete mental or physical activities" (Buckworth, Dishman, O'Connor & Tomporowski, 2013, p. 245). Previous research shows that employee fatigue largely results from prolonged work stress (Bültmann, Kant, Van den Brandt & Kasl, 2002; Seidler et al., 2014), and thus is 'work-related'. It has been estimated that 18% of employees in Europe show high levels of work-related fatigue (Milczarek, Schneider & González, 2009). Work-related fatigue can best be understood as a continuum, ranging from acute fatigue that for instance occurs after a work day and disappears after a relatively short rest period, to a severe and persistent form of fatigue that occurs after a long period of (work) stress. This 'end-stage' of the continuum is often labelled 'burnout' (Schaufeli, Leiter & Maslach, 2009). Burnout mainly refers to feelings of mental and physical exhaustion (i.e., extreme levels of fatigue), low mood and lack of energy (Schaufeli, Leiter & Maslach, 2009). Although many researchers favor a multifaceted definition of burnout that also includes cynicism and reduced professional efficacy (Schaufeli, Leiter & Maslach, 2009), consensus exists that exhaustion is the key component of burnout (Brenninkmeijer & Van Yperen, 2003; Kristensen, Borritz, Villadsen & Christensen, 2005; Schaufeli, Leiter & Maslach, 2009).

Both in science and practice, the terms 'fatigue', 'exhaustion' and 'burnout' are to some extent used interchangeably. What these concepts share is that they refer to fatigue symptoms that are more or less prevalent in employees. To prevent confusion, in the current thesis, we will mostly use the term 'work-related fatigue' or simply 'high levels of fatigue'. Doing so, we point to serious persistent fatigue that can be attributed to prolonged stress in the work context.

Consequences of work-related fatigue

High levels of work-related fatigue are associated with substantial losses in employees' health and well-being. More specifically, fatigued employees show reduced self-efficacy levels (Alarcon, Eschleman & Bowling, 2009), poorer sleep (Ekstedt et al., 2006), decreased cognitive functioning (Deligkaris, Panagopoulou, Montgomery & Masoura, 2014; Oosterholt, Van der Linden, Maes, Verbraak & Kompier, 2012), reduced work ability (Arvidson, Börjesson, Ahlborg, Lindegård & Jonsdottir, 2013), a higher risk for developing cardiovascular diseases (Melamed, Shirom, Toker, Berliner & Shapira, 2006), and lower physical fitness (Gerber, Lindwall, Lindegård, Börjesson & Jonsdottir, 2013). Employers face consequences such as lost productivity time and presenteeism (Demerouti, Le Blanc, Bakker, Schaufeli & Hox, 2009; Ricci, Chee, Lorandeau & Berger, 2007; Toppinen-Tanner, Ojajärvi, Väänänen, Kalimo & Jäppinen, 2005). Estimations of annual costs to society caused by work-related fatigue vary from 136.4 billion dollar (figures related to the U.S.; Ricci, Chee, Lorandeau & Berger, 2007) to 200 billion euro (figures related to Europe; Eurofound, 2012). Given the high prevalence of work-related fatigue and its negative consequences for employees, employers and society, it is valuable to examine potential approaches to reduce it.

Exercise and work-related fatigue

Evidence is emerging that regular exercise constitutes an effective approach to reduce work-related fatigue. Exercise can be defined as physical activity that is "planned, structured, repetitive and purposeful in the sense that the improvement or maintenance of one or more components of physical fitness is the objective" (Caspersen, Powell, Christenson, 1985, p. 126). Exercise is a subcategory of physical activity. The latter is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure" (Caspersen, Powell, Christenson, 1985, p.126). Assets of exercise for the reduction of fatigue include its accessibility, low costs, and positive 'side effects', such as reduced risk for cardiovascular diseases (Warburton, Nicol & Bredin, 2006). Various pathways have been proposed to explain the relationship between exercise and work-related fatigue, yet the underlying mechanisms are still uncertain. Probably, a combination of psychological and physiological mechanisms is responsible for the positive effects of exercise on fatigue.

As to psychological working mechanisms, it has been proposed that exercise facilitates psychological detachment from work, and in this way reduces the risk of prolonged stress responses such as fatigue (Geurts & Sonnentag, 2006; Sonnentag, 2012). Exercise may also increase people's self-efficacy (Craft 2005; Joseph, Royse, Benitez & Pekmezi, 2014), and generate positive feelings about the self (Feuerhahn, Sonnentag & Woll, 2014; Joseph, Royse, Benitez & Pekmezi, 2014). These feelings of competence may 'spill over' to the work domain, resulting in employees who feel more competent in coping with their work tasks (Feuerhahn, Sonnentag & Woll, 2014; Rook & Zijlstra, 2006), and as such experience their work tasks as less demanding. Lower perceived demands may contribute to lower fatigue (Hockey, 2013).

As regards physiological working mechanisms, it has been suggested that by means of regular exercise, the body is 'toughened up' and thus better able to handle (psychological) stress (i.e., cardiovascular fitness hypothesis; Colcombe & Kramer, 2003). This may result in faster bodily recovery after stress exposure, and reduce the risk of persistent fatigue (Jackson & Dishman, 2006; Klaperski, Von Dawans, Heinrichs & Fuchs, 2014). Exercise may also induce changes in several neurotransmitters and neuromodulators resulting in better mood and increased energy (see Dishman et al., 2006 and Schuch et al., 2016 for overviews).

In line with these proposed working mechanisms, available studies support the notion that exercise may reduce work-related fatigue. Cross-sectional and longitudinal studies have reported an inverse relationship between the two (Ahola, Pulkki-Raback, Kouvonen, Rossi, Aromaa & Lonnyvist, 2012; Bernaards et al., 2006; Bültmann, Kant, Kasl, Schröer, Swaen & Van den Brandt, 2002; Jonsdottir, Rödjer, Hadzibajramovic, Börjesson & Ahlborg, 2010; Lindwall, Gerber, Jonsdottir & Börjesson, 2014). The few available intervention studies also show beneficial effects of exercise on work-related fatigue (Bretland & Thorsteinsson, 2015; Freitas, Carneseca, Paiva & Paiva, 2014; Gerber et al., 2013; Tsai et al., 2013; Van Rhenen, Blonk, Van der Klink, Van Dijk & Schaufeli, 2005). Furthermore, a large body of research suggests that exercise helps to reduce depression (Schuch et al., 2016) and chronic fatigue syndrome (Larun, Brurberg, Odgaard-Jensen & Price, 2016), conditions that share similarities with work-related fatigue (Bianchi, Schonfeld & Laurent, 2015; Huibers et al., 2003). Although these earlier studies lay down the first foundation for the effect of exercise on work-related fatigue, causal inferences as regards exercise as an effective approach to reduce work-related fatigue cannot be drawn due to several limitations present in these earlier studies.

Limitations of earlier research into the effect of exercise on work-related fatigue

We propose the following main limitations in earlier research hindering strong causal inferences about the relationship between exercise and work-related fatigue: i) lack of well-designed exercise intervention studies aimed at reducing work-related fatigue; and related to i, ii) lack of process evaluations in exercise intervention studies aimed at reducing work-related fatigue; and iii) lack of insight in possible 'reciprocal' causation between exercise and work-related fatigue. Beneath, we explain each limitation in more detail and we describe which steps we believe need to be taken to overcome this limitation.

Exercise intervention studies aimed at reducing work-related fatigue

In order to allow for strong causal inferences about exercise as an effective approach to reduce work-related fatigue, well-designed intervention studies are needed. Overall, the few available intervention studies that investigated the effect of exercise on work-related fatigue show beneficial effects (Bretland & Thorsteinsson, 2015; Gerber et al., 2013; Lindegård, Jonsdottir, Börjesson, Lindwall & Gerber, 2015; Tsai et al., 2013; Van Rhenen, Blonk, Van der Klink, Van Dijk & Schaufeli, 2005; except Freitas, Carneseca, Paiva & Paiva, 2014). From these studies it appears that (non-)aerobic exercise - one to three times a week for 4 to 18 weeks - has promising effects on reducing work-related fatigue. Beneficial effects were visible in employees with (non-clinical) fatigue (Bretland & Thorsteinsson, 2015), stress (Van Rhenen, Blonk, Van der Klink, Van Dijk & Schaufeli, 2005) and clinical burnout (Gerber et al., 2013; Lindegård, Jonsdottir, Börjesson, Lindwall & Gerber, 2015). In one study it was also found that exercise is equally effective compared to cognitive behavioral therapy (Van Rhenen, Blonk, Van der Klink, Van Dijk & Schaufeli, 2005).

Despite these efforts in earlier intervention studies, firm inferences regarding the causal association between exercise and reductions in work-related fatigue cannot be drawn, due to methodological shortcomings in these pioneering studies. Several methodological flaws can be noted in the aforementioned studies: a) lack of control conditions (Freitas, Carneseca, Paiva & Paiva, 2014; Gerber et al., 2013; Lindegård, Jonsdottir, Börjesson, Lindwall & Gerber, 2015); b) no (described) randomization procedure (Lindegård, Jonsdottir, Börjesson, Lindwall & Gerber, 2015; Tsai et al., 2013); c) combination of exercise and other intervention ingredients (Van Rhenen, Blonk, Van der Klink, Van Dijk & Schaufeli, 2005); and d) lack of intention-to-treat analyses (Bretland & Thorsteinsson, 2015; Freitas, Carneseca, Paiva & Paiva, 2014; Gerber et al., 2013; Lindegård, Jonsdottir, Börjesson, Lindwall & Gerber, 2015; Tsai et al., 2013; Van Rhenen, Blonk, Van der Klink, Van Dijk & Schaufeli, 2005). Control conditions are important for internal validity, i.e., the extent to which the outcome from an intervention can be attributed to the intervention ingredient (i.e., exercise) and not to alternative explanations (Mohr et al., 2009). Sound randomization procedures minimize systematic differences between conditions in known and unknown factors that may affect intervention effects (Mohr et al., 2009). When intervention ingredients are combined it is unknown to what extent found beneficial effects were due to exercise or rather other intervention components (Ekkekakis, 2015). Furthermore, importantly, none of the previous intervention studies analyzed the results according to the intention-to-treat principle. The intention-to-treat principle is described as "once randomized, always analyzed" (Gupta, 2011). This means that all participants who are randomized need to be included in the analyses, irrespective of noncompliance or anything that happens after randomization. This is important because in every intervention study it is common that participants deviate from the intervention protocol: they may withdraw from the intervention, not receiving all intervention components, or dropout. Intention-to-treat analysis is considered the most cautious analyzing approach. It minimizes Type 1 error (i.e., detecting an effect that is not present). It also helps to preserve comparable groups that are brought about by randomization, and to limit inferences based on ad hoc subgroups of participants in the intervention study (Gupta, 2011). Furthermore, as intention-to-treat analysis acknowledges non-compliance, which is very common in practice, it gives insight in the extent to which intervention outcomes can be translated into practice (Gupta, 2011). As none of the previous intervention studies analyzed participants according to the intention-to-treat principle, it is possible that previous estimates of intervention efficacy are overoptimistic.

A suitable strong intervention design that acknowledges methodological shortcomings of previous research is the randomized controlled trial (RCT) (Kristensen, 2005). It includes random assignment of participants to at least one intervention arm and a control group. Due to randomization and the inclusion of a control group several forms of bias, such as selection bias (i.e., selective enrolling of participants in a trial based on what the next intervention allocation is likely to be), are controlled for (Nelson & Mathiowetz, 2004). By definition, a RCT entails a longitudinal design: it should have one measurement before the intervention and at least one after to allow for the investigation of change over time. The effect evaluation of a RCT incorporates examining the difference in change between the intervention and the control group. We can speak in terms of *effect* ('causality'), since the randomization ensures equal groups and the intervention took place before the effect (Kristensen, 2005).

Process evaluation of exercise interventions

Effect evaluation of well-designed intervention studies is essential to allow for causal inferences, but it is not enough (Moore et al., 2015). In case of effect evaluation, emphasis is placed on a comparison between outcomes before and after the intervention period. Consequently, what happens during the intervention period remains a 'black box'. However, during the intervention period many things could happen that affect intervention outcomes, e.g., the intervention is not delivered as intended, participants are differently exposed to intervention ingredients, and participants appraise the intervention in various ways (Kristensen, 2005; Moore et al., 2015; Murta, Sanderson & Oldenburg, 2007; Nielsen & Randall, 2013; Steckler & Linnan, 2002). Therefore, not only effect evaluation, but also process evaluation needs to be considered when evaluating interventions. Process evaluation opens the 'black box' to see what happened during the intervention period. It explores the implementation (i.e., the way a program is put into practice), receipt (i.e., dose and views of participants) and setting (i.e., general intervention and implementation context) and helps in interpreting intervention outcomes (Durlak, 2015; Kompier & Aust, 2016; Murta, Sanderson & Oldenburg, 2007; Steckler & Linnan, 2002).

Process evaluation is important for distinguishing between interventions that are not correctly designed and those that are not correctly delivered (Kristensen, 2005; Nelson & Mathiowetz, 2004). A truly effective intervention could be found to be not effective because it was not implemented as intended. In another scenario, a truly ineffective intervention could be found to be effective, because an alternative effective intervention was implemented in its place. Either scenario has negative consequences for researchers and practice who use this information (Kristensen, 2005; Nelson & Mathiowetz, 2004). Process evaluation also aids in explaining positive intervention effects (Steckler & Linnan, 2002). If an intervention lead to significant outcomes and is implemented as intended, understanding which process factors contributed to intervention success may help to refine theory and improve intervention effectiveness (Steckler & Linnan, 2002).

Process evaluation is often challenging and difficult (Kristensen, 2005), because many process variables can play a role in variation in intervention effects (Durlak, 2015). Several conceptual frameworks for guiding process evaluation have been proposed (e.g., Fridrich, Jenny & Bauer, 2015; Moore et al., 2015; Nielsen & Randall, 2013; Saunders, Evans & Joshi, 2005; Steckler & Linnan, 2002). These frameworks emphasize that an intervention should have a grounded theory that explains why and how the intervention would have a positive effect. A key element in these frameworks is the 'dose' (the quantity of intervention implemented). A distinction is made between 'dose delivered' (the quantity of intervention elements that is provided by interventionists) and 'dose received' (the quantity of intervention elements that participants actually receive; also referred to as 'exposure' or 'compliance'). Another central element is 'fidelity' (i.e., whether the content of the intervention is delivered as intended). Dose and fidelity are the most studied and essential elements of process evaluations (Durlak, 2015). Other relevant key elements are 'participant appraisal' (i.e., how participants experience the intervention), and 'context' (i.e., the general intervention and implementation setting).

As far as we know, process evaluation of exercise interventions for work-related fatigue has as yet received no attention. Consequently, what happens during exercise interventions for work-related fatigue remains largely a 'black box'. Conducting process evaluations of exercise interventions aimed at reducing work-related fatigue, in addition to effect evaluations, would help to get a more comprehensive understanding of exercise intervention and its effects on work-related fatigue. Understanding when, how and why intervention effects can be (best) achieved may help in designing future effective exercise interventions for work-related fatigue and aid in successfully implementing the intervention(s) in practice (Biron & Karanika-Murray, 2013; Durlak, 2015; Hulscher, Laurant & Grol, 2003; Murta et al., 2007; Steckler & Linnan, 2002). This information is relevant for researchers, funders, policy makers and practice (Biron & Karanika-Murray, 2013; Steckler & Linnan, 2002).

Exercise and work-related fatigue: a two-way street?

Traditionally, research into the exercise – fatigue relationship has taken a one-way street perspective: does exercise reduce work-related fatigue? However, one may also conceive this relationship as bi-directional. This is the perspective of a two-way street with exercise having an impact on fatigue, and – the other way around – with fatigue having an impact on exercise. This latter direction is also theoretically plausible. Generally, fatigue is seen as an adaptive phenomenon: it is a stop emotion to protect for an excessive depletion of energy stocks (Ament & Verkerke, 2009; Meijman, 2000). When fatigued, people have a lower tendency to start or complete a task, especially when this task requires high effort (Hockey, 2013). As exercise requires high effort, it can be assumed that high fatigue levels negatively affect employees' exercise level. This hypothesis also receives support from studies into self-regulation which suggest that fatigue hinders self-regulatory or self-control abilities (Inzlicht, Berkman & Elkins-Brown, 2016; Muraven, Tice & Baumeister, 1998), which are needed for (continued) exercise engagement (Olson, 2014). Cross-sectional studies that attempted to investigate this relationship showed that employees experiencing higher levels of work-related fatigue do indeed report lower exercise levels (Ahola et al., 2012; Gorter, Eijkman & Hoogstraten, 2000). However, based on such a design, the direction of causality cannot be inferred.

For better insight in the direction of causality between exercise and work-related fatigue, other study designs are needed. A longitudinal study with a full-panel design is an effective way of examining the association between each variable at an earlier time point with the other variable at a later time point (Zapf, Dormann & Frese, 1996). In this way one can establish a temporal precedence and a statistical association – both of which are required for a true causal relation (Taris & Kompier, 2014). In such a design, three types of causation can be investigated: 'normal causation' (i.e, exercise → work-related fatigue), 'reversed causation' (i.e., work-related fatigue → exercise) and 'reciprocal causation' (i.e., exercise ⟷ work-related fatigue).

Aim of this thesis

Because it is as yet hard to firmly answer the question whether exercise reduces work-related fatigue, and since it is therefore unknown whether an exercise program can be effectively applied as an intervention to reduce work-related fatigue, the general aim of this thesis is to advance knowledge about the extent to which exercise is effective in reducing work-related fatigue.

To this aim, three related empirical studies with strong methodological designs were carried out. In these studies we addressed the three aforementioned main limitations of previous studies: i) lack of well-designed exercise intervention studies aimed at reducing work-related fatigue; ii) lack of process evaluations in exercise intervention studies aimed at reducing work-related fatigue; and iii) lack of knowledge of potential bi-directional relations between exercise and work-related fatigue. Below we explain how we addressed these three limitations and elaborate on the rationale for these studies.

To address the first limitation (i.e., lack of well-designed exercise intervention studies aimed at reducing work-related fatigue), we conducted two RCTs. In both studies we studied individuals with high levels of fatigue. They were randomly assigned to either a six-week exercise intervention or a wait list control condition. This enabled us to test the effect of exercise on work-related fatigue compared to the 'natural course' of fatigue. The exercise interventions included supervised (two one-hour sessions a week) and unsupervised (one one-hour session a week) low-intensity running, for six consecutive weeks. Effect evaluation was based on pre-, post- and follow-up measurements. All participants who were randomized were analyzed (i.e., according to the intention-to-treat principle, see Gupta, 2011). In order to be transparent, we preregistered both trials in a trial registry that met all requirements for proper registration (De Angelis et al., 2004). Our registration was – according to guidelines – performed before participant enrollment, and accessible to the public.

The sample in the first RCT (Study 1) consisted of students with high levels of study-related fatigue, but who were still able to study. We chose a student sample in this RCT since it has been shown that a considerable number of students do experience high levels of study-related fatigue (the prevalence being estimated at 10%; Boot, Vonk & Meijman, 2007; Schmidt & Simons, 2015). We argue that the concept of study-related fatigue among students resembles that of work-related fatigue among employees, since students' activities include attending classes and making assignments, which are, just like work, structured, time demanding, goal-directed and largely obligatory activities (Schaufeli & Taris, 2005). Hence, from a psychological perspective, the core activities of students resemble those of employees (Schaufeli, Martinez, Marques Pinto, Salanova & Bakker, 2002; Schaufeli & Taris, 2005). The primary outcome was study-related fatigue. In order to get a broader picture of intervention effects, several secondary outcomes were also investigated (i.e., sleep, self-efficacy, cognitive functioning and physical fitness).

In the second RCT (Study 2) we studied employees with high levels of work-related fatigue. They were still able to work. Work-related fatigue was the primary outcome in this RCT. Secondary outcomes included self-efficacy, sleep, work ability, cognitive functioning and aerobic fitness. The set-up of this RCT was largely similar to the students-study, but – based on this first RCT – some improvements were made. We used a more reliable and valid physical fitness test (Oja, Laukkanen, Pasanen, Tyry & Vuori, 1991), and included two new secondary outcomes (i.e., work-related self-efficacy and work ability). Furthermore, we offered the complete study protocol of this RCT for publication. This enabled us to receive external expert opinions on our methods, ultimately leading to quality improvements in (descriptions of) the protocol (Eysenbach, 2004).

With regard to the second limitation (i.e., lack of process evaluations in exercise intervention studies), in both RCTs we performed weekly inter-measurements on process variables and well-being indicators. Process variables were only measured among exercisers and included exposure (also referred to in the literature as 'compliance' or 'dose delivered') and participants' experiences of the intervention. Studying exposure helps to distinguish between interventions that are not correctly designed and those that are not correctly delivered (Durlak, 2015; Hulscher, Laurant & Grol, 2003; Kristensen, 2005; Murta et al., 2007; Steckler & Linnan, 2002). We also studied experiences that accompanied the intervention, such as enjoyment (how one feels about exercise; Raedeke, 2007), psychological detachment (i.e., disengaging oneself psychologically from study or work demands; Ragsdale, Beehr, Grebner & Han, 2011, Sonnentag & Fritz, 2015) and effort (experienced exercise intensity; Borg, 1998, Ekkekakis, Parfit & Petruzello, 2011). Differences in these experiences may impact intervention effectiveness (Hulscher, Laurent & Grol, 2003; Nielsen & Randall, 2012). Moreover, by measuring well-being indicators among both participants in the exercise and wait list control condition during the six intervention weeks, we could identify the point in time at which well-being trajectories of exercisers and controls started to differentiate. Hence, it enabled us to examine 'when' intervention effects became visible.

We addressed the third limitation in Study 3, which was a longitudinal study with a two-wave full-panel design and a one-year time lag. Bi-directional relationships were studied between exercise and work-related fatigue (i.e., 'normal', 'reversed' and 'reciprocal' relationships; De Lange, Taris, Kompier, Houtman & Bongers, 2004). The study was conducted in a national representative sample of Dutch working population. We assessed the level of work-related fatigue and the number of days that these employees engaged in at least 30 minutes of moderate-intensity physical activity. The latter measurement reflected the physical activity norm, which states that people of 18 years or older should engage in at least 30 minutes of moderate-intensity physical activity on at least five days a week (Hildebrandt, Chorus & Stubbe, 2010). We investigated whether engaging in more days of physical activity was associated with a decrease in future levels of work-related fatigue, and whether higher levels of work-related fatigue were associated with a decrease in future physical activity. Moreover, inspired by previous studies that investigated the cross-sectional and longitudinal relationships between the quality of working life and employees' physical activity (Fransson et al., 2012; Kouvonen et al,. 2013), we also investigated the relation between work demands and physical activity.

Outline of this thesis

The next chapters present the results of these empirical studies. The outline of these chapters reads as follows:

Chapter 2 presents the RCT conducted among students with high levels of study-related fatigue. We investigated to what extent a six-week exercise intervention was effective in reducing three indicators of study-related fatigue (emotional exhaustion, overall fatigue, and need for recovery). Effects of exercise on secondary outcomes (sleep, self-efficacy, physical fitness, and cognitive functioning) were also investigated, as well as whether effects were maintained on the longer term (4 and 12 weeks after the end of the intervention).

Chapter 3 describes the study protocol of the RCT among employees with high levels of work-related fatigue. We adopted a design that is similar to the RCT in Chapter 2. Follow-up measurements were carried out 6 and 12 weeks after the end of the intervention. Primary outcomes included three indicators of work-related fatigue (emotional exhaustion, overall fatigue, and need for recovery). Secondary outcomes were similar to those investigated in Chapter 2, but now also included work self-efficacy and work ability.

Chapter 4 provides the effect evaluation of the RCT among employees. In this RCT we wanted to better understand to what extent compliance with the intervention protocol was associated with a variation in intervention effects. Therefore, in our statistical approach we systematically distinguished between those who were randomized (intention-to-treat analyses), and those who complied with their intervention protocol (per-protocol analyses).

Chapter 5 presents the process evaluation of the RCT among students. We took a closer look at the development of fatigue and other relevant indicators of well-being for fatigued students throughout the intervention period. We examined how several relevant process variables were related to the development well-being indicators over time.

Chapter 6 presents a longitudinal study in which bi-directional causal relationships were investigated between a) physical activity and work-related fatigue, and b) physical activity and work demands. In order to obtain a more detailed insight in these relationships, we also investigated whether a meaningful change in physical activity (i.e., upward or downward change in compliance with the international physical activity norm) was associated with a change in work-related fatigue and work demands.

Lastly, in **Chapter 7** the main findings of our empirical studies are summarized and discussed. We acknowledge limitations of our work and provide suggestions for future research. We also discuss the theoretical and practical implications of this work.

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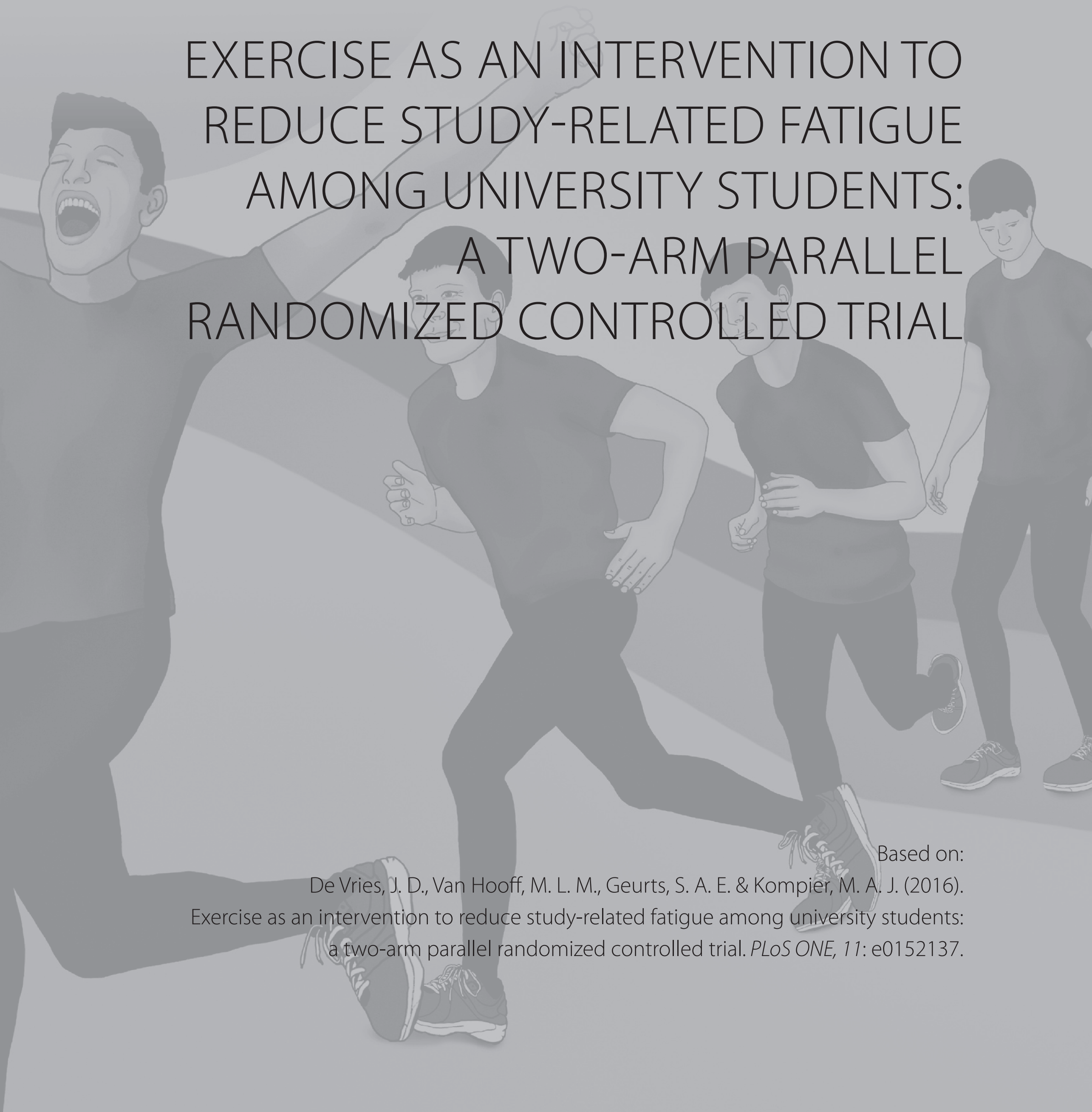
CHAPTER 2

EXERCISE AS AN INTERVENTION TO REDUCE STUDY-RELATED FATIGUE AMONG UNIVERSITY STUDENTS: A TWO-ARM PARALLEL RANDOMIZED CONTROLLED TRIAL



Based on:
De Vries, J. D., Van Hooff, M. L. M., Geurts, S. A. E. & Kompier, M. A. J. (2016).
Exercise as an intervention to reduce study-related fatigue among university students:
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Abstract

Purpose

Many university students experience high levels of study-related fatigue. This high prevalence, and the negative impact of fatigue on health and academic performance, call for prevention and reduction of these symptoms. The primary aim of the current study was to investigate to what extent an exercise intervention is effective in reducing three indicators of study-related fatigue (emotional exhaustion, overall fatigue, and need for recovery). Effects of exercise on secondary outcomes (sleep quality, self-efficacy, physical fitness, and cognitive functioning) were also investigated.

Methods

Participants were students with high levels of study-related fatigue, currently not exercising or receiving other psychological or pharmacological treatments, and with no medical cause of fatigue. They were randomly assigned to either a six-week exercise intervention (low-intensity running three times a week, n = 49) or wait list (no intervention, n = 48). All participants were measured before the intervention (T0), and immediately after the intervention (T1). Exercisers were also investigated 4 weeks (T2) and 12 weeks (T3) after the intervention.

Results

Participants in the exercise condition showed a larger decrease in two of the three indicators of study-related fatigue (i.e., overall fatigue and need for recovery) as compared to controls. Additionally, sleep quality and some indicators of cognitive functioning improved more among exercisers than among controls. No effects were found for self-efficacy, and physical fitness. The initial effects of the exercise intervention lasted at follow-up (T2 and T3). At 12-week follow up (T3), 80% of participants in the exercise condition still engaged in regular exercise, and further enhancements were seen for emotional exhaustion, overall fatigue, and sleep quality.

Conclusion

These results underline the value of low-intensity exercise for university students with high levels of study-related fatigue. The follow-up effects that were found in this study imply that the intervention has the potential to promote regular exercise and accompanying beneficial effects in the longer run.

Introduction

University students are often faced with study stress, resulting from high study demands, and concern about academic grades (Lingard, 2007; Schaufeli, Martínez, Marques Pinto & Salanova, Bakker, 2002). When this study stress is prolonged and exceeds students' adaptive resources, it can result in high levels of study-related fatigue (Balogun, Hoeberlein-Miller, Schneider & Katz, 1996; Jacobs & Dodd, 2003; Law, 2007) or in burnout (a more severe expression of study-related fatigue; Schaufeli, Martínez, Marques Pinto, Salanova & Bakker, 2002). A substantial number of university students experience study-related fatigue (e.g., estimated at 10% in the Netherlands – the country under study; Schmidt & Simons, 2015), and it is expected that this number will further increase (Mailey et al., 2010), for instance due to increased performance demands (e.g., in the Netherlands, a minimum number of European credits is required in order to continue the study), and increased financial study costs (e.g. from 2015, in the Netherlands students no longer receive a governmental study gift, but a study loan, see: Vossensteyn, Cremonini, Epping, Laudel & Leisyte, 2013). The prevalence of study-related fatigue, and its negative impact on health (Maslach, Schaufeli & Leiter, 2001) and on academic performance (Campos, Jordani, Zucoloto, Bonafé & Maroco, 2012), call for prevention and reduction of these complaints.

Evidence is emerging that regular exercise may be an accessible and inexpensive way to prevent or reduce (study-related) fatigue (Bernaards et al., 2006; Carson, Baumgartner, Matthews & Tsouloupas, 2010; Gerber et al., 2013; Jonsdottir, Rödjer, Hadzibajramovic, Börjesson & Ahlborg, 2010). Both psychological and physiological working mechanisms may underlie potential positive effects of exercise on study-related fatigue. With respect to the former (see Otto & Smits [2011] for an overview), exercise may, for instance, help students to distract from (negative) thoughts about study demands ('psychological detachment'; Sonnentag, 2012). Detachment by means of exercise may enable students to return to a relaxed psychophysiological state that enhances the feeling of being refreshed by the start of a new (study) day (Geurts, 2013; Geurts & Sonnentag, 2006; Rook & Zijlstra, 2006). Regarding the latter it is, for instance, hypothesized that individuals who exercise regularly - compared to those who do not exercise - show faster physiological (e.g., blood pressure) recovery from a stressor once the stressor is no longer present (Dishman & Jackson, 2006; Salmon, 2001), which decreases the likelihood that persistent fatigue occurs (Geurts & Sonnentag, 2006). The few available intervention studies concerning (study-related) fatigue show favorable effects of exercise, but research in this area can be advanced, as these studies did not include a control group (Gerber et al., 2013) or focused on general fatigue instead of study-related fatigue (Puetz, Flowers & O'Connor, 2008). To our knowledge, well designed randomized controlled trials to examine the efficacy of exercise for reducing study-related fatigue have as yet not been conducted. Therefore, the first aim of the current study was to investigate to what extent an exercise intervention (i.e., low intensity running, three times a week) is effective in reducing study-related fatigue. To this purpose, we carefully selected students with high levels of study-related fatigue and randomly assigned them to either an exercise intervention or wait list in order to establish to what extent the exercise intervention reduced fatigue (primary outcome) as compared to the natural course of time. In accordance with the proposed working mechanisms, and with available research pointing to the beneficial effects of exercise on fatigue (Gerber et al., 2013; Puetz, Flowers & O'Connor, 2008), we expect that:

Hypothesis 1: The exercise intervention reduces study-related fatigue.

Additionally, we aimed to obtain insight in the extent to which the exercise intervention is effective in improving four (secondary) outcomes relevant for students with high levels of study-related fatigue, to get a better understanding of a possible broader impact of the intervention. First, it was investigated whether exercise benefits sleep. Research shows that high levels of fatigue are linked to lower sleep quality (Pagnin et al., 2014). For instance, it has been found that fatigued individuals spend less time in the sleep stages of slow wave and rapid eye movements sleep (Ekstedt et al., 2006). Spending enough time in these sleep stages is indicative of good sleep quality, and a requisite for feeling rested during the day and for adequate (academic) performance (Curcio, Ferrara & De Gennaro, 2006). It has been argued that exercise promotes more sleep in these stages (Driver & Taylor, 2000), although it is not exactly clear why this is the case. Several hypotheses have been proposed. One hypothesis is that the raised body temperature resulting from exercise is the link to better sleep quality (see for an overview of hypotheses: Driver & Taylor, 2000). Based on proposed mechanisms and available evidence, we hypothesize:

Hypothesis 2a: The exercise intervention improves sleep quality.

It has also been argued that exercise extends sleep duration, because the physical tiredness resulting from the effort expended during exercise may promote falling asleep (Driver & Taylor, 2000). Therefore, we expect:

Hypothesis 2b: The exercise intervention improves sleep duration.

Second, it was investigated whether exercise benefits self-efficacy. Research shows that higher levels of fatigue are associated with lower self-efficacy (Shoji et al., 2015). It has been proposed that exercise generates self-efficacy through mastery experiences: individuals who are successful in fulfilling challenging tasks (such as exercise) by means of their own efforts develop abilities that foster confidence in themselves (Craft, 2005; McAuley, Mailey, Szabo & Gothe, 2013). As the sample under study consists of students who did not engage in regular exercise before the intervention, we assume that exercise is a challenging task.

Therefore, we expect that:

Hypothesis 2c. The exercise intervention improves self-efficacy.

Third, it was examined whether the exercise intervention improves physical fitness. There is irrefutable evidence that regular exercise benefits physical fitness (Haskell et al., 2007). As we selected students who did not engage in regular exercise, we expect that gains can be obtained with respect to their physical fitness when they adopt a regular exercise pattern. Therefore, we propose:

Hypothesis 2d. The exercise intervention improves physical fitness.

Fourth, the effect of exercise on cognitive functioning was studied. Fatigued individuals often report difficulties in everyday cognitive performance, such as slow thinking, and they perform worse on objectively measured cognitive functioning (Deligkaris, Panagopoulou, Montgomery & Masoura, 2014). An emerging body of research points towards the idea that exercise improves (certain aspects) of cognitive functioning, especially the executive functions (Hillman, Erickson & Kramer, 2008). It has been argued that these improvements occur, since exercise stimulates the growth of new neurons (i.e. 'neurogenesis') in certain areas in the brain, such as the hippocampus that is associated with learning and memory (Van Praag, 2008). Based on current insights, we expect:

Hypothesis 2e. The exercise intervention improves cognitive functioning.

The final objective of this study was to investigate whether the effects of the exercise intervention would last on the longer term, and whether the follow-up effects were strongest for participants who spend more time on exercise during the follow-up period. To this purpose, we investigated whether intervention effects persisted at 4 weeks and 12 weeks after the intervention. Since we expect participants to have become accustomed to exercising regularly (i.e. to have developed an exercise-habit) and therefore continue running, we expect that:

Hypothesis 3a: The positive effects of the intervention are maintained at 4-week and 12-week follow-up.

As can be assumed that participants who exercise (more) regularly after the intervention are more exposed to the beneficial working mechanisms of exercise, we expect:

Hypothesis 3b: The follow-up effects are strongest for participants who spend more time on exercise during the follow-up period.

Methods

Participants were randomly assigned to one of two parallel groups, in a 1:1 ratio. It was investigated whether the exercise intervention was superior to wait list. The study protocol was approved by Ethical Commission Social Sciences of the Radboud University (registration number: ECSW2013-1811-142). Additionally, the study protocol was registered in the Netherlands Trial Register before recruiting participants (NTR; see http://www.trialregister.nl): NTR4412. In the study protocol it was stated that participation in daily life (social interaction with family, friends, and student networks) would be assessed as well (i.e., secondary outcome). As we did not find a proper measure for this outcome, we preferred to not include this outcome in the current study.

Eligibility criteria

Eligible participants were university students reporting high levels of study-related fatigue, defined by a score above validated cut-off points on two measures of (study-related) fatigue: ≥2.2 on the Emotional Exhaustion Scale of the Utrecht Burnout Scale for Students (UBOS-S; Schaufeli, Martínez, Marques Pinto, Salanova & Bakker, 2002; Schaufeli & Van Dierendonck, 2000) and ≥ 22 on the Fatigue Assessment Scale (FAS; De Vries, Michielsen, Van Heck & Drent, 2004). Participants were excluded if at the time of the study screening they a) exercised more than one hour a week; b) received psychological or pharmacological treatment for their fatigue complaints; c) reported a medical cause of their fatigue; d) were addicted to drugs, and e) were physically unable to run.

Procedure

The study took place at the Radboud University (The Netherlands) from January 2014 to August 2014. Students were approached through different channels: by short recruitment talks during lectures, the Radboud University's Research Participation System, social media, and flyers. Those interested in participation could fill out the UBOS (emotional exhaustion) and the FAS (overall fatigue) questionnaires on the study's website (www.runtervention.nl). If participants scored ≥2.2 on the UBOS, and ≥22 on the FAS, they were asked to answer questions to assess the other criteria for eligibility. If they were eligible to participate, they visited the first author or a research assistant to read and sign informed consent, and to complete other baseline measures. Next, the randomization procedure was conducted.

Randomization

The randomization procedure was conducted in a blocked fashion. We planned to deliver the intervention in groups of 10 participants. Of every block of 20 participants, 10 were allocated to the exercise intervention and 10 to the wait list. Participants were given a sealed and opaque envelope with the allocation. After opening the envelope, participants were allowed to tell the researcher in which group they were allocated.

Exercise intervention

The exercise intervention comprised six weeks in which participants ran three times a week: twice a week in a group of ten people under supervision of a licensed running trainer and once independently (they were allowed to run with others). The running sessions took place outdoors on Tuesdays and Thursdays from 6 PM until 7 PM. Participants were instructed to run on a low intensity, in a pace that allowed them to have a conversation during running. The ability to converse during exercise has been shown to match low intensity exercise (Persinger, Foster, Gibson, Fater & Porcari, 2004). Low intensity was chosen because this intensity is preferable for lowering fatigue (Loy, O'Connor & Dishman, 2013; Puetz, Flowers & O'Connor, 2008), and because it reduces the risk of injuries (Hreljac, 2004). In addition, participants were advised to keep at least one day of rest (i.e. no running) in between the running sessions to diminish the risk of injuries. Furthermore, participants were told that the focus during running was not on running as long or as fast as possible, but rather on 'feeling good'.

Two trainers supervised each running group, with each trainer supervising one running session a week. Trainers were all members of the Dutch Foundation of Running Therapy, a foundation focused on offering running to people with psychological complaints (www.runningtherapie-nederland.nl). Trainers had at least two years of experience in giving Running Therapy, and had been trained in psychopathology, physiology, and running training principles. Trainers were instructed to observe participants' running intensity (i.e. make sure that all participant were able to have a conversation during running) and keep the focus on 'feeling good'.

Each running session comprised 60 minutes: a warming up of about 15 minutes (running on a low intensity alternated with walking and flexibility exercises), a core program consisting of running alternated with walking of about 30 minutes, and a cooling down of about 15 minutes. During the six weeks, the periods of running in each running session were extended, and the walking periods shortened, so that after six weeks the participants were able to run 20 minutes uninterrupted on a low intensity.

Control condition

During the six weeks of the exercise intervention, the participants in the control condition were on a wait list and thus received no intervention. After these six weeks, they were given the opportunity to follow the exercise intervention as well.

Primary and secondary outcomes

Primary and secondary outcomes were measured pre (T0), and post (T1) intervention among all participants. Those in the experimental condition were also measured at follow-up: 4 weeks (T2), and 12 weeks after the intervention period (T3). At follow-up, physical fitness was only measured at T3, since 4 weeks constitutes a relatively short time to notice differences in physical fitness (Wenger & Bell, 1986). Due to possible learning effects (Chan, Shum, Toulopoulou & Chen, 2008), cognitive functioning was not measured at follow-up.

Study-related fatigue was measured with three indicators: emotional exhaustion, overall fatigue and need for recovery. We based the inclusion criteria on the first two indicators only, since a validated cut off score for need for recovery does not exist.

Emotional exhaustion was measured with a Dutch adaptation of the Maslach Burnout Inventory (MBI; Maslach, Jackson & Leiter, 1996): Utrecht Burnout Scale (Schaufeli & Van Dierendonck, 2000). We used a modified version that was especially developed for students (UBOS-S; Schaufeli, Martínez, Marques Pinto, Salanova & Bakker, 2002). From this questionnaire, the 'Exhaustion' scale was used, consisting of 5 items, answered on a 7-point Likert scale. An example question is: "I feel burned out from my studies" (0 = *never*, 6 = *always; every day*). A mean score was computed. A mean score ≥ 2.2 is considered as 'high' emotional exhaustion (Schaufeli & Van Dierendonck, 2000). Cronbach's alpha ranged between .81 (T1) and .90 (T4).

Overall fatigue was measured with the 10-item Fatigue Assessment Scale (FAS), developed and validated by De Vries, Michielsen, Van Heck and Drent (2004). An example question is: "I am bothered by fatigue". Items were rated on a 5-point Likert-scale (1 = *never*, 5 = *always*). A sum score was computed, and a score of ≥ 22 is determined as a 'high' level of fatigue (De Vries, Michielsen, Van Heck and Drent, 2004). Cronbach's alphas ranged between .79 (T1) and .88 (T4).

Need for recovery was assessed with the 6-item 'Need for Recovery Scale' (Van Veldhoven & Meijman, 1994). We adapted the scale for students, meaning that 'work' was replaced by 'study'. An example item is "I find it hard to relax at the end of a day of studying", and all items were rated on a 4-point Likert scale (1 = *(almost) never*, 4 = *(almost) always*). A mean score was computed. Cronbach's alpha ranged from .75 (T1) and .87 (T4).

Sleep

To assess *sleep quality*, a sum score was computed of six items adapted from the sleep quality scale of the Questionnaire on the Experience and Evaluation of Work (VBBA; Van Veldhoven & Meijman, 1994). The questions tapped into the three main components of insomnia (Roth, 2007): 'difficulty initiating sleep' (1 item, i.e., "I have difficulties falling asleep"), 'difficulty maintaining sleep' (2 items, e.g. "I often wake up during the night"), and 'non-restorative sleep' (2 items, e.g. "Most of the time, I feel refreshed when I wake up" [reversed]). Furthermore, there was one overall question for sleep quality: "I often sleep well". All items had a dichotomous answer category: 1= *yes*, 0 = *no*. Positively formulated items were reversed, and a sum score was calculated, so that a higher score indicates more sleep complaints. Cronbach's alphas ranged between .61 (T1) to .76 (T4). In addition, *sleep quantity* (mean hours of sleep a night) was questioned.

Self-efficacy

To measure *self-efficacy*, the 12-item General Self Efficacy Scale was used (GSES-12; Bosscher & Smit, 1998). An example item is: 'When I make plans, I am certain I can make them work'. A mean score was computed of all items, rated on a 5-point Likert scale (1= *strongly disagree*, 5= *strongly agree*). Cronbach's alphas ranged between 0.80 (T1) and 0.86 (T2).

Physical fitness was measured with the Conconi test (Conconi et al., 1996). Although the test received some critics (see Bosquet, Léger & Legros, 2002), it has been argued that it provides an appropriate indicator of the heart rate deflection point on which physical fitness can be assessed (Bodner & Rhodes, 2000). The test was performed on a stationary cycle ergometer in the Radboud University Sport Centre. Participants wore a heartrate belt, and were instructed to cycle as long as physically possible and to keep their cadence between 70-80 rpm. Before starting the actual test, participants completed a warm-up procedure, consisting of 4 minutes of low-intensity cycling. The start intensity (power – the number of watts) was based on weight and age and thus differed between participants. During the test, the wattage gradually increased, and the time cycling per watt interval gradually decreased. After finishing the test, the heart rate deflection point was determined by the software (e.g. the point at which the heart rate – power relationship deviates from linearity; see Bosquet, Léger & Legros, 2002). Estimated Vo_2max ml/kg/min was based on the heart rate deflection point, the number of watts, age, and gender (Conconi et al., 1997). Completion of the test took about 20 minutes.

Cognitive functioning was measured with one self-report measure, and three objective performance tests. These tests measured three types of executive functioning: updating, inhibition, and switching (Oosterholt, Van der Linden, Maes, Verbraak & Kompier, 2012).
Self-reported cognitive functioning was measured with the Dutch translation of the Cognitive Failures Questionnaire (CFQ; Broadbent, Cooper, FitzGerald & Parkes, 1982). It consists of 25 items rated on a 5-point Likert scale (1= *never*, 5 = *very often*), and an example question is: "Do you find you forget appointments?". A mean score was computed. The reliability of the scale ranged between $\alpha = 0.83$ (T1) and $\alpha = 0.90$ (T2).

Updating refers to constant monitoring and fast addition/deletion of information in working-memory (Miyake et al., 2000) and was assessed by the 2-Back task (Kirchner, 1958). The test consisted of 284 letters that were displayed one-by-one in the centre of a computer screen. The letters were 'b', 'd', 'g', 'p', 't', and 'v' and were both displayed as capital and small letters. Stimulus duration was set at 450 ms with the interval between two stimuli fixed on 750 ms. Once a letter appeared that was similar to a letter that had appeared two stimuli before, participants had to push a button on a button-box (target rate 32.5%). For a correct response, no distinction was made between capital and small letters. Completion of the test took about seven minutes. The number of correct responses was used as a measure for updating.

Inhibition addresses the suppression of dominant but irrelevant automatic responses to stressors (Miyake et al., 2000) and was measured by the Sustained Attention to Response Test (SART; Robertson, Manly, Andrade, Baddeley & Yiend, 1997). A total of 450 digits (ranging from 1-9) were displayed one-by-one in the centre of a computer screen in a random fashion. Participants had to push a button on a button-box each time when they saw a digit, except if the digit was '3' (target rate 11.1%). Digits were displayed for 250 ms and the interval between digits was fixed at 850ms. Completion of the test took about eight minutes. The number of 'correct inhibitions' (not pressing the button when a '3' was displayed) constituted the measure for inhibition.

Switching refers to the ability of shifting between different tasks (Miyake et al., 2000) and was measured with the Matching task (Poljac et al., 2010). In each trial of the test, four different geometric figures (circle, hexagon, square and triangle) were displayed in four different colours (blue, green, red and yellow) in the lower half of the screen. Also, a coloured reference geometric figure was shown in the upper half of the screen. The participants had to match the reference figure (in the upper half of the screen) to one of the four figures (in the lower half of the screen) according to shape or colour. The combination between colour and shape figures was presented in such a way that there was one correct answer. Whether participants had to match according to shape or colour, was (randomly) indicated by a cue that was displayed for 1000ms. Participants could push one of the four buttons on a keyboard that corresponded to each of the four match figures in the lower half of the screen. Participants had to push the button as fast as possible. The whole test consisted of 31 task runs, each consisting of on average six trials (range: 4-8 trials). For all the trials during one task run, one cue was given (matching according to shape or colour). During the test, half of all task runs consisted of 'switch' runs, in which the type of cue differed from the previous run. The other half consisted of 'repetition' runs, in which the type of cue was identical to the previous run. The duration of the test was about six minutes. The reaction time of the first trial of the 'switch' or the 'repetition' runs was used as a measure for 'switching' and 'repetition' respectively. Runs in which the cue was not correctly followed or in which no response was given, were not included in the analyses.

To obtain a full assessment of cognitive functioning, we additionally explored the *subjective costs* (fatigue, motivation, demands, and effort) associated with performing the cognitive tests (Hockey, 2013; Meijman & Mulder, 1992; Oosterholt et al., 2014). Before doing the cognitive tests, participants rated how motivated they were to do the tests. Fatigue was measured prior to and after the tests. After completing all the tests, participants were asked how demanding the tests had been, and participants indicated how much effort they spent when doing the tests. The *subjective costs* of doing the cognitive tests were measured by using single item measures, answered on a scale from 1 (*not at all*) to 10 (*very much*).

Exercise behaviour

At T4 (follow-up after 12 weeks), participants in the exercise condition were asked to indicate how frequently and how many minutes a week they exercised in general during the 12-week follow-up period after the intervention.

Power analysis

To determine the number of participants, a power analysis was conducted in the program G*Power (Faul, Erdfelder, Lang & Buchner, 2007). This analysis was based on a repeated measures MANOVA (RM-MANOVA) with time as within subjects factors and condition as between subjects factor. This analysis showed that a total of 90 participants was required in order to detect a medium effect of .30 (Pillai's V) on study-related fatigue outcome from pre to the immediate post intervention, given a two-sided 5% significance level and a power of 80%. A comparable previous study showed a medium effect size as well (Puetz, Flowers & O'Connor, 2008). Because we anticipated a dropout rate of about 20%, we intended to recruit 108 participants. During the study, however, the dropout turned out to be low. Consequently, it was decided to stop recruiting after the number of 100 participants had been reached (five blocks of 20 participants).

Statistical analyses

We used SPSS version 19 to analyze the data (IBM, 2010). The statistical analyses were based on the intention-to-treat principle (Moher, Schulz & Altman, 2001). This means that all participants who were randomized were included in the analyses (i.e., also those who ended their participation before or during the intervention period).

Pearson correlations (*r*) were used to explore whether the three indicators of study-related fatigue were inter-related. In order to test whether the exercise intervention was effective in reducing these three indicators of study-related fatigue (*H1*), a RM-MANOVA was conducted with 'time' (pre [T0] versus post intervention [T1]) as within-subjects factor and 'condition' as between-subjects factor ('intervention' versus 'wait list'). For the effects of the exercise intervention, we were interested in the Group x Time interactions of these RM-(M)ANOVAs, since an interaction indicates that the change in the outcome over time is different between conditions.

Additionally, to investigate the extent to which the intervention resulted in clinical meaningful changes (Jacobson & Truax, 1991) in the primary outcomes emotional exhaustion and fatigue, a Chi Square Test was performed to examine if the proportion of participants that were 'recovered' at T1 (for burnout: <2.2 on the UBOS; for fatigue: <22 on the FAS) differed between the exercise and the wait list condition. An effect size (φ) between .2 - .5 was considered as small, .5 - .8 as medium, and >.8 as large (Ferguson, 2009).

Separate repeated measures (M)ANOVAs were done with 'time' (pre [T0] versus post intervention [T1]) as within-subjects factor and 'condition' as between-subjects factor ('intervention' versus 'wait list') to investigate the effect of the exercise intervention on sleep (*H2a* and *H2b*), self-efficacy (*H2c*), and physical fitness (*H2d*). The four indicators of cognitive functioning (*H2e*), and subjective costs were also separately analyzed by means of a (M) ANOVA. The Matching Task was analyzed using a 2 x 2 x 2 mixed design with 'run type' (switch versus repetition) and 'time' (pre [T0] versus post intervention [T1]) as within factors and 'condition' as between factor ('intervention' versus 'wait list').

To find out whether intervention-effects would persist during the follow-up period (*H3a*) among participants in the exercise condition (i.e. participants in the control condition were not measured at follow up, because during this period they received the exercise intervention), separate RM-(M)ANOVAs for the outcomes were performed with 'time' (pre [T0] vs. post intervention [T1] vs. 4 weeks after the intervention period [T2] vs. and 12 weeks after the intervention period [T3]) as within-subjects factor. Since physical fitness was not measured at T2, the RM-ANOVA for this outcome included three time points (T0, T1, and T3). If the time effect of the RM-(M)ANOVA was significant, post hoc tests were conducted to exactly determine between what time points the outcome had changed. Since Bonferroni correction for multiple comparisons is often too conservative, we used the Sidak correction instead (Abdi, 2007).

For all RM- (M)ANOVAs, an effect size (η^2) between .01 - .06 was considered as small, .06 - .14 as medium, and > .14 as large (Cohen, 1988). Significant interactions effects were further examined by means of paired t-tests, for which Cohen's *d* was used as an effect size.

In order to investigate whether follow-up effects were moderated by the amount of exercise participants engaged in during the follow-up period (*H3b*), the amount of exercise during this 12 week follow up period (number of minutes a week) was added as covariate in a RM-(M)ANCOVA with 'time' (post intervention [T1] versus follow up after 12 weeks [T3]) as within factor. We were interested in the interaction between the amount of exercise and time, since this indicates that the development over time in a certain outcome is moderated by the amount of exercise participants engage in. The follow up effects at 4 weeks after the intervention (T2) were not taken into account, because exercise was measured as the 'mean number of minutes a week during the 12 weeks after the intervention'.

Results

Descriptives

The baseline characteristics of participants in each of both conditions are presented in Table 2.1. There were no differences between conditions at baseline. The participants were recruited in the period of February 2014 to May 2014.

The participant flow diagram is depicted in Figure 2.1. For the self-report measures, 49 of 50 participants in the exercise condition and 48 of 49 participants in the control condition completed all questionnaires. However, not every participant completed the physical fitness test. Reasons were: injury (*n*=3 [controls]), not willing to do the test for unknown reasons (*n*=3), not able to do the exercise due to extreme fatigue (*n*=1), and not enough data points to estimate the Vo_2max due to very low physical fitness (*n*=1).

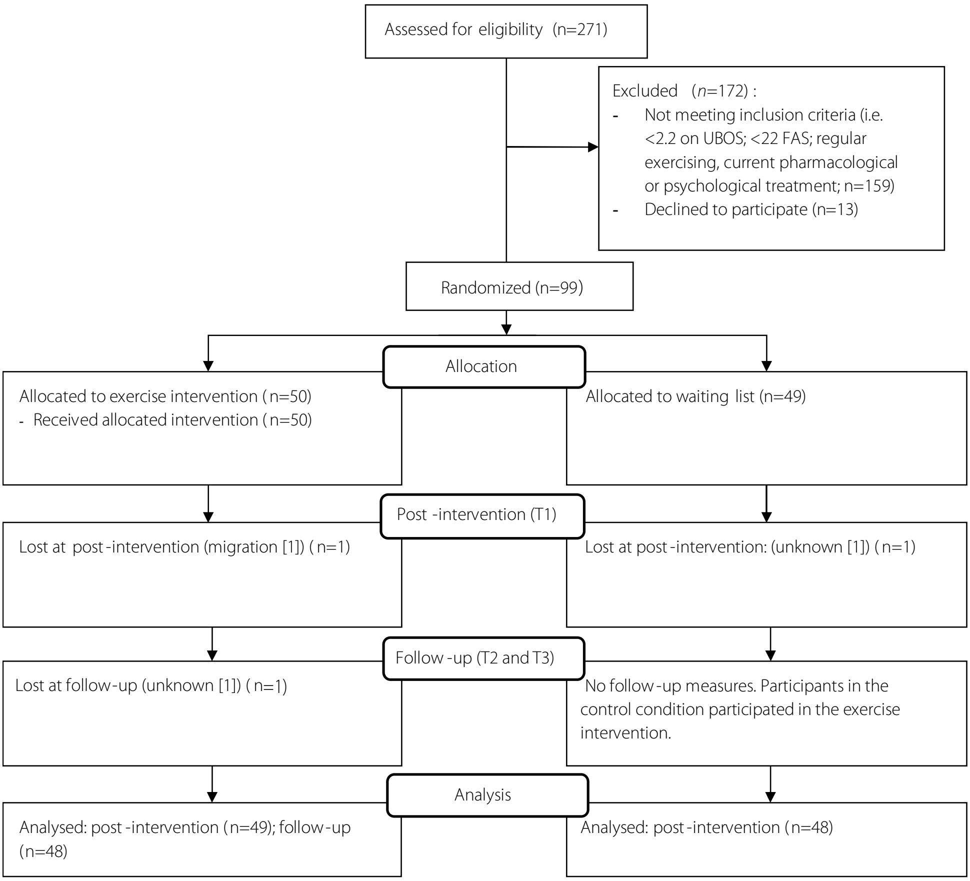

Figure 2.1. CONSORT Flow Diagram.

In the exercise condition, four participants dropped out during the intervention: reasons were injuries (*n*=3) and migration (*n*=1). Those who got injured, continued to participate in the measurements of the study. Overall, the compliance during the exercise intervention was high: on average 14.16 (*Standard Deviation [SD]*=3.61) of the in total 18 running sessions were carried out.

In the control condition, most participants did not exercise during the intervention period. Only two participants in the control condition started to engage in regular exercise, for on average 75 minutes and 100 minutes a week respectively. After the intervention period, 40 of the initial 49 participants in the control condition participated in the exercise intervention.

Table 2.1. *Background characteristics at study entry.*

	Exercise condition (*n* = 50)	Control condition (*n* = 49)
Age, years (mean ± *SD*)	20.9 ± 2.5	20.7 ± 2.2
Male *n* (%)	9.0 (18.0)	10.0 (20.4)
Dutch *n* (%)	39.0 (78.0)	33.0 (67.3)
German *n* (%)	11.0 (22.0)	16.0 (32.7)
Hours of study a week (mean ± *SD*)	26.9 ± 12.5	26.7 ± 10.8
Study: Psychology *n* (%)	37.0 (74.0)	34.0 (69.4)
Study enjoyment (mean ± *SD*)[a]	7.8 ± 0.8	7.9 ± 1.1
Additional job *n* (%, mean hours ± *SD*)	22.0 (44.0, 6.6 ± 3.9)	21.0 (42.9, 9.1 ± 5.3)

[a] 1 = no enjoyment at all, 10 = very high level of enjoyment

Effects on primary outcome (Hypothesis 1)

Study-related fatigue

The three indicators of study-related fatigue were significantly inter-related (at T0: emotional exhaustion and overall fatigue r = .63; emotional exhaustion and need for recovery r = .35; overall fatigue and need for recovery r = .36). A significant multivariate Group x Time interaction effect was found for the combination of the three indicators of study-related fatigue ($F(3,93) = 3.00$, $p = .026$, $\eta^2 = .10$). As the multivariate test was significant, we examined univariate main effects. In Table 2.2, the Group x Time interaction for emotional exhaustion was not significant, but Group x Time interactions reached significance for overall fatigue (F = 4.85, η^2 = .05) and need for recovery (F = 7.66, η^2 = .08). Participants in the exercise condition showed a stronger decrease in overall fatigue ($t(48)$ = 6.82, p = < .001; Cohen's d: 0.90) than those in the control condition ($t(47)$ = 3.08, p = .003; Cohen's d: 0.46). Additionally, the exercise intervention resulted in a stronger decrease over time in need for recovery ($t(48)$= 7.42, p <.001; Cohen's d: 0.84) compared to the control condition ($t(47)$ = 2.59, p = .013; Cohen's d: 0.42).

Table 2.2. *Mean (SD) scores of emotional exhaustion, overall fatigue, need for recovery, sleep quality, sleep duration, self-efficacy, and physical fitness pre (T0) and post intervention (T1), at follow-up after 4 weeks (T2) and at follow-up after 12 weeks (T3) per condition. (Table continues on next page)*

Outcome (theoretical range)	T0		T1		Intervention effects			T2	T3	Follow-up effects		
	Exercise *M (SD)*	Control *M (SD)*	Exercise *M (SD)*	Control *M (SD)*	Effect	F^a	η^2	Exercise *M (SD)*	Exercise *M (SD)*	F^b	Effect[c]	Δ*M*
Emotional Exhaustion (0-6)	3.74 (1.05)	3.78 (0.84)	2.76 (1.16)	3.03 (1.06)	G	0.75	.01	2.57 (1.03)	2.27 (1.09)	**38.65****	**T0 vs T2**	**1.16****
					T	66.15**	.41				T1 vs T2	0.24
					GxT	1.23	.01				**T0 vs T3**	**1.46****
											T1 vs T3	**0.53***
											T2 vs T3	0.29
Overall fatigue (10-50)	30.47 (5.52)	30.92 (4.91)	25.35 (5.86)	28.29 (6.52)	G	2.78	.03	25.46 (5.64)	23.31 (5.50)	**38.51****	**T0 vs T2**	**4.89****
					T	46.67**	.33				T1 vs T2	0.06
					GxT	**4.85***	**.05**				**T0 vs T3**	**6.92****
											T1 vs T3	**2.09***
											T2 vs T3	**2.02***
Need for Recovery (1-4)	2.55 (0.61)	2.36 (0.50)	2.05 (0.58)	2.15 (0.49)	G	0.19	.00	2.06 (0.59)	1.97 (0.61)	**26.56****	**T0 vs T2**	**0.49****
					T	45.53**	.32				T1 vs T2	0.00
					GxT	**7.66***	**.08**				**T0 vs T3**	**0.57****
											T1 vs T3	0.09
											T2 vs T3	0.09
Sleep quality (0-6)	3.08 (1.62)	2.71 (1.40)	2.16 (1.64)	2.75 (1.64)	G	0.15	.00	2.11 (1.90)	1.70 (1.79)	**15.86****	**T0 vs T2**	**-0.94****
					T	7.85*	.08				T1 vs T2	-0.11
					GxT	**9.41***	**.09**				**T0 vs T3**	**-1.34****
											T1 vs T3	**-0.51***
											T2 vs T3	-0.40

Table 2.2. *Mean (SD) scores of emotional exhaustion, overall fatigue, need for recovery, sleep quality, sleep duration, self-efficacy, and physical fitness pre (T0) and post intervention (T1), at follow-up after 4 weeks (T2) and at follow-up after 12 weeks (T3) per condition. (Continued)*

Outcome (theoretical range)	T0		T1		Intervention effects			T2	T3	Follow-up effects		
	Exercise *M (SD)*	Control *M (SD)*	Exercise *M (SD)*	Control *M (SD)*	Effect	F^a	η^2	Exercise *M (SD)*	Exercise *M (SD)*	F^b	Effect[c]	Δ*M*
Sleep duration (hours)	7.39 (1.10)	7.50 (1.80)	7.45 (0.87)	7.42 (0.90)	G T G*T	0.05 0.02 0.38	.00 .00 .01	7.43 (0.77)	7.47 (1.04)	0.16	T0 vs T2 T1 vs T2 T0 vs T3 T1 vs T3 T2 vs T3	0.06 -0.02 0.08 0.04 0.04
Self efficacy (1-5)	3.31 (0.52)	3.23 (0.58)	3.38 (0.59)	3.17 (0.61)	G T GxT	1.75 0.04 2.92	.02 .00 .03	3.41 (0.51)	3.44 (0.54)	1.49	T0 vs T2 T1 vs T2 T0 vs T3 T1 vs T3 T2 vs T3	-0.08 -0.04 -0.10 -0.05 -0.02
Vo_2max^d	28.45 (5.46)	27.93 (4.14)	29.39 (5.19)	28.35 (3.95)	G T GxT	0.67 4.69* 0.63	.01 .05	[e]	29.65 (5.40)	2.67	T0 vs T3 T1 vs T3	-1.11 -0.26

Note. Relevant effects are in bold; *M* = Mean, *SD* = Standard Deviation, *F* = *F*-statistic, Δ*M* = change in mean, η^2 = effect size, G = Group effect, T = Time effect; GxT = Group x Time effect

[a] Univariate effect of (M)ANOVAs with 'time' (pre vs. post) as within subjects factor and 'condition' (exercise vs. control) as between subjects factor; [b] Time effect pre (T0) vs post (T1) vs 4 weeks after the intervention (T2) vs 12 weeks after the intervention (T3), only for the exercise condition; [c] Post hoc tests using Sidak correction; [d] 8 missing values; [e] Vo_2max was not assessed at T2.

* *p* = <.05; ** *p* = <.01

Table 2.3 shows the extent to which the intervention resulted in clinical meaningful changes in emotional exhaustion and overall fatigue (i.e. participants who recovered from T0 to T1; for emotional exhaustion: <2.2 on the UBOS; for fatigue: <22 on the FAS). Chi Square tests revealed that, for emotional exhaustion, the proportion of recovered participants was marginally higher in the exercise condition than in the control condition ($\chi^2(1) = 3.72$, $p = .054$, $\varphi = .196$). For overall fatigue, the proportion of recovered participants was higher in the exercise condition ($\chi^2(1) = 4.738$, $p = .036$, $\varphi = .212$). Taken together, the results generally support *Hypothesis 1*, as we found that participants in the exercise intervention showed a larger decrease in overall fatigue and need for recovery over time compared to the wait list controls.

Table 2.3. *Stability and change: percentages of participants who improved, recovered, unimproved or deteriorated on emotional exhaustion, and overall fatigue from T0 to T1.*

	Improved *n* (%)	Recovered *n* (%)	Unimproved or deteriorated *n* (%)
Exercise condition (n=49)			
Emotional exhaustion	42 (85.7)	19[1] (38.8)	7 (14.3)
Fatigue	40 (86.0)	16[2] (32.7)	9 (18.4)
Control condition (n=48)			
Emotional exhaustion	37 (77.1)	10[1] (20.4)	11 (22.9)
Fatigue	33 (68.8)	7[2] (14.6)	15 (31.3)

Note. [1] lower than 2.2 on the UBOS at T1; [2] lower than 22 on the FAS at T1.

Effects on secondary outcomes (Hypotheses 2a to 2e)

Sleep

A significant multivariate Group x Time interaction effect was found for sleep ($F(2,94) = 4.73$, $p = .011$, $\eta^2 = .09$). Univariate tests (see Table 2.2) revealed a significant Group x Time interaction for sleep quality ($F = 9.41$, $\eta^2 = .09$), in support of *Hypothesis 2a*. T-tests showed that sleep quality improved in the exercise condition ($t(48) = -3.97$, $p < .001$, Cohen's d: 0.56), but not in the control condition ($t(48) = 0.20$, $p = .844$, Cohen's d: -0.03). In the absence of a significant Group x Time interaction effect for sleep duration, *Hypothesis 2b* was not supported.

Self-efficacy

For self-efficacy, no significant Group x Time effect was found ($p = .091$; see Table 2.2). Hence, *Hypothesis 2c* was not supported.

Physical fitness

No Group x Time effect for physical fitness was found (see Table 2.2). Therefore, *Hypothesis 2d* was not supported.

Cognitive functioning

Table 2.4 shows the results of the RM-(M)ANOVAs for cognitive functioning. A significant Group x Time interaction was found for self-reported cognitive functioning (F= 26.60, η^2 = .22). T-tests revealed that 'exercisers' showed a decrease in cognitive failures over time (t(48) = 5.85, p = < .001, Cohen's d: 0.87), while no such change was found in the control condition (t(47) = -0.80, p = .429, Cohen's d: -0.07).

Mixed results were found for the cognitive tests. It is important to note that technical problems caused inadequate recording of the T1-reaction times for some participants: for 9 participants with respect to the 2-back test (updating), and for 17 participants with respect to the SART (inhibition). Analyses were only conducted for participants with adequate recordings. For inhibition (SART) we found a significant Group x Time interaction (F= 5.98, η^2 = .07). Additional t-tests showed that participants in the exercise condition improved (t(40)= -2.35, p = .024, Cohen's d: 0.41), whereas those in the control condition did not (t(36)= 1.08, p = .290, Cohen's d: -0.06). No significant Group x Time interactions for updating (2-back test) and switching (Matching Task) were found.

Table 2.4 also shows the subjective costs of cognitive test performance. The RM-MANOVA revealed a significant multivariate effect of the combined subjective costs (F(5,86) = 3.88, p = .003, η^2 = .18). Considering univariate effects, both at T0 and T1, all participants were motivated to conduct the cognitive tests (mean scores ranging from 7.93 to 8.27), and participants' motivation did not change (over time) between conditions (no significant 'Group' and 'Group x Time' interaction). There were significant interaction effects for 'fatigue' before (F = 10.54, η^2 = .08) and after (F = 8.50, η^2 = .08) the intervention. T-tests indicate that exercisers, over time, became less fatigued before performing the cognitive tests (t(47)= 4.35, p = < .001, Cohen's d: 0.84) and also less fatigued after having performed the cognitive tests (t(47)= 3.70, p = .001, Cohen's d: 0.65), when compared to controls (before: t(46)= 0.36, p = .719), Cohen's d: 0, and after: t(45)= -0.15, p = .878, Cohen's d: -0.02). The non-significant 'difference' interaction effect indicates that both groups became equally tired from the test battery at both points in time. A significant Group x Time interaction was found for demands though (F= 7.32, η^2 = .08). Exercisers considered the tests less demanding over time (t(47)= 4.48, p < .001), while controls did not (t(44)= 1.23, p = .227). The non-significant Group x Time interaction of 'effort' indicates no across time difference for the amount of effort expended when conducting the cognitive tests. Taking these results together, we found partial support for *Hypothesis 2e* (decreased cognitive failures, increased inhibition, and decreased demands during the tests).

Table 2.4. *Results for cognitive functioning pre (T0) and post intervention (T1) per condition.*

Outcome (Theoretical range) [Task used]	Pre (T0) Exercise *M (SD)*	Pre (T0) Control *M (SD)*	Post (T1) Exercise *M (SD)*	Post (T1) Control *M (SD)*	Effect	*F*	*η²*
Cognitive Failures (1-5)	2.90 (0.44)	2.75 (0.45)	2.51 (0.46)	2.79 (0.61)	G T **GxT**	.492 17.72** **26.60****	.01 .16 **.22**
Updating [2-Back Task][a]	62.16 (12.20)	65.77 (12.81)	73.07[1] (11.72)	74.42[2] (13.12)	G T GxT	1.02 83.68** 1.12	.01 .49 .01
Inhibition [SART][a]	21.17 (7.12)	24.69 (7.79)	24.37[3] (8.42)	24.14[4] (8.76)	G T **GxT**	1.44 1.03 **5.98***	.02 .01 **.07**
Switching [Matching Task]							
RT repetition[b]	929.51 (183.36)	923.33 (164.83)	800.74 (129.54)	838.05 (129.54)	G T	.04 67.07**	.00 .42
RT switch[b]	1014.88 (187.21)	1013 (219.79)	908.87 (152.27)	902.68 (167.43)	Rt RtxG RtxT GxT RtxGxT	61.35** 0.74 0.01 0.53 1.38	.40 .01 .00 .01 .02
Motivation (1-10)	8.27 (1.51)	8.05 (1.40)	8.06 (1.74)	7.93 (1.45)	G T GxT	0.37 1.44 0.13	.01
Fatigue (1-10)							.00
Before[c]	6.35 (1.71)	5.73 (2.02)	4.77 (2.02)	5.73 (2.18)	G T **GxT**	0.24 10.54* **10.54***	.01
After[d]	7.31 (1.36)	7.07 (1.50)	6.23 (1.92)	7.11 (1.61)	G T **GxT**	1.17 5.58* **8.50***	.02
Difference[e]	0.96 (1.38)	1.27 (1.91)	1.46 (1.65)	1.39 (1.73)	G T GxT	0.18 2.47 1.71	.00 .03 .01
Demands (1-10)	7.47 (1.22)	7.35 (1.07)	6.73 (1.37)	7.20 (1.08)	G T **GxT**	0.64 16.17** **7.32***	.01 .16 **.08**
Effort (1-10)	7.87 (1.35)	7.68 (1.18)	7.79 (1.66)	7.59 (1.45)	G T GxT	0.52 0.53 0.00	.01 .01 .00

Note. M = Mean, *SD* = Standard Deviation, *F* = F-test, *ΔM* = change in mean, η^2 = effect size, G = Group effect, T = Time effect; GxT = Group x Time effect

[a] Correct responses; [b] Reaction times in milliseconds; [c] Score before making the cognitive tests; [d] Score after making the cognitive tests; [e] Difference score between fatigue before and after making the cognitive tests

[1] 4 missing values; [2] 5 missing values; [3] 7 missing values; [4] 11 missing values

* *p* = <.05; ** *p* = <.01

Follow-up effects (Hypothesis 3a)

Table 2.2 shows the means and standard deviations of the primary and secondary outcomes at 4 weeks (T2) and 12 weeks (T3) after the intervention, for the exercisers only (the controls could no longer serve as controls during the follow-up as they started to exercise themselves). For the three combined indicators of study-related fatigue, repeated measures MANOVA showed a large multivariate effect of 'time' ($F(9,38) = 13.16$, $p < .001$, $\eta^2 = .76$). Univariate effects (see Table 2.2), were found for all three indicators (emotional exhaustion: $F = 38.65$, $\eta^2 = .46$; overall fatigue: $F = 38.51$, $\eta^2 = .46$; need for recovery: $F = 26.56$, $\eta^2 = .37$). Post host tests revealed that exercisers showed a decrease in emotional exhaustion, overall fatigue and need for recovery from baseline (T0) to follow-up (both at T2 and T3). In addition, emotional exhaustion and overall fatigue further decreased from T1 (post intervention) to T3 (12 weeks after the intervention).

With respect to sleep, we found a large significant multivariate effect ($F(6,41) = 5.37$, $p < .001$, $\eta^2 = .44$). As can be seen in Table 2.2, the univariate effect of sleep quality was significant ($F = 15.86$, $\eta^2 = .26$). No change over time was found for sleep duration. Post hoc tests displayed an increase in sleep quality from baseline (T0) to follow-up (both at T2 and T3), and from post intervention (T1) to 12 weeks after the intervention (T3). No significant time effects were found for self-efficacy and physical fitness, meaning that these outcomes did not change over time during follow up among the exercisers.

In summary, we found further improvements from post intervention to 12 weeks after the intervention in emotional exhaustion, overall fatigue and sleep quality. Therefore, we conclude that *Hypothesis 3a* is partially supported.

Exercise maintenance in relation to follow-up effects (Hypothesis 3b)

A total of 40 participants (from 50 in the exercise condition) engaged in regular exercise during the follow up period, for an average of 113.93 minutes ($SD = 88.51$) a week, in on average 2.55 ($SD = 1.34$) exercise sessions a week.

For study-related fatigue, sleep, and self-efficacy, we did not find significant interaction effects between the covariate 'exercise' and 'time' (F's ranging from to 0.00 to 2.88, all p's $> .05$). This means that follow-up effects were not moderated by the amount of exercise participants engaged in during the follow-up period. For physical fitness, the RM-ANCOVA showed a significant interaction between time and exercise $F(1,43) = 4.53$, $p = .039$). To interpret this interaction effect, we constructed two subgroups based on the minutes of exercise a week: < 60 minutes, and ≥ 60 minutes a week. Inspecting the means of these groups revealed that exercisers with ≥ 60 minutes of exercise during the follow-up period showed an increase in physical fitness compared to less active participants. Therefore, we conclude that *Hypothesis 3b* is partly supported, since we only found support for this hypothesis with respect to physical fitness.

Discussion

The aim of the present study was to investigate: i) to what extent an exercise intervention was effective in reducing study-related fatigue (primary outcome) among university students; ii) whether the exercise intervention was able to improve four secondary outcomes that are related to high levels of study-related fatigue (sleep, self-efficacy, physical fitness, and cognitive functioning); and iii) whether the effects of the exercise intervention were maintained on the longer term.

As to the first aim, it can be concluded that the exercise intervention is effective in reducing study-related fatigue. We found that – compared to controls – 'exercisers' showed a larger decrease in two of the three indicators of study-related fatigue (i.e., overall fatigue and need for recovery) after the intervention period. Additionally, we showed that exercisers fell more often below validated cut-off scores of overall fatigue after the intervention period as compared to controls, implying that the changes found in overall fatigue can be considered clinically meaningful (Jacobson & Truax, 1991). By supporting a relation between exercise and reduced levels of fatigue, these findings extend previous research also showing an inverse relationship between these two constructs (e.g. Larun, Brurberg, Odgaard-Jensen & Price, 2015; Puetz, Flowers & O'Connor, 2008). It is probable that biological (e.g., faster cardiovascular recovery after stress exposure; Dishman & Jackson, 2006) as well as psychological mechanisms (i.e., psychological detachment; Sonnentag, 2012) are responsible for this relation. Our study, however, offers no definitive conclusions about the exact mechanisms that may mediate the reduction in study-related fatigue among exercisers.

One unanticipated finding was that exercisers did not show a larger improvement in emotional exhaustion than the control group. Instead, both groups showed a decrease over time in this outcome. This decrease in both groups may be confounded by the timing of this study during the course of the study year. That is, the post-intervention measurements were done in the period between May and July, and in this period (in the Netherlands) students know whether they have earned enough European credit points to be admitted to the next study year. This may decrease study stress and accompanying fatigue. As – compared to the other two measures of fatigue – the emotional exhaustion-measure is most explicitly related to fatigue as a consequence of the study, this may contribute to the decrease in this outcome in both groups.

As to our second aim, the exercise intervention proved to be effective in improving sleep quality. Inspection of the separate items of the sleep quality scale revealed that especially 'non-restorative sleep' (i.e. feeling not refreshed when waking up) improved among participants in the exercise condition (results can be obtained from the first author). Contrary to expectations, we did not find an effect of exercise on sleep duration. This result may be explained by the fact that, at pre-intervention, 82.83% of the students already slept between the 7-9 hours that are recommended for young adults of 18-25 years of age (Hirschkowitz et al., 2015), which left not that much potential for improvement.

Based on the idea that exercise generates feelings of personal mastery, we expected the exercise intervention to increase participants' self-efficacy. However, no such effect was found. One explanation for this non-significant finding may be that – at least during the relatively short duration of the intervention period - exercise does not benefit self-efficacy in general, but rather affects participants' 'exercise self-efficacy'. This type of self-efficacy specifically refers to confidence in one's ability to exercise on a regular basis and has indeed been found to be improved after exercise interventions (McAuley, Mailey, Szabo & Gothe, 2013).

We did not find the expected improvement in physical fitness among students who received the exercise intervention. It is possible that the intensity of running in this study was too low to induce substantial changes in VO_2max. Indeed, a previous study by Puetz, Flowers and O'Connor (2008) also failed to find changes in VO_2max in fatigued students who received low intensity exercise for six weeks, but did find such changes among students who received moderate intensity exercise for six weeks. Yet another possibility is that the measurement of physical fitness, which was based on the Conconi paradigm, lacks validity (Bodner & Rhodes, 2000; Bosquet, Léger & Legros, 2002; Conconi et al., 1996). At least, our results seem to illustrate that a change in VO_2max is no precondition for fatigue to reduce, as is basically suggested by the cardiovascular fitness hypothesis (Colcombe & Kramer, 2003). We did find that more time spent on exercise during the follow-up period was related to higher VO_2max at the 12-week follow-up.

The exercise intervention under study was effective in improving some of the indicators of cognitive functioning. Exercisers showed a larger improvement in self-reported cognitive functioning in daily life and a larger decrease in how demanding they experienced the cognitive tests as compared to controls. This latter decrease could be attributed to the lower fatigue levels exercisers displayed after the intervention period (Meijman & Mulder, 1992). We also found a larger improvement in objectively measured inhibition in the exercise group. This finding should be interpreted with caution, though, since it could also be attributed to baseline differences between the two conditions and a tendency toward the mean. Thus, although an improvement in self-reported cognitive functioning was found, this result did only slightly co-occur with changes in objective cognitive performance. A certain dissimilarity between self-reported and objectively measures of indicators of cognition has also been found in previous research (Oosterholt, Van der Linden, Maes, Verbraak & Kompier, 2012; Oosterholt, Maes, Van der Linden, Verbraak & Kompier, 2014), and clear explanations have not yet been provided. Overall, the results of the current study are in line with earlier meta-analyses demonstrating inconclusive results of exercise on cognitive performance (Smith et al., 2010; Verburgh, Königs, Scherder & Oosterlaan, 2014). To develop a full picture of the relation between exercise and cognitive functioning, additional studies will be needed. For instance it is still not known which type, intensity or frequency of exercise is best for optimal effects on cognition (Verburgh, Königs, Scherder & Oosterlaan, 2014).

Regarding the third aim of this study, we indeed found that the beneficial effects of the intervention were maintained at 4 and 12 weeks after the intervention. Additionally, emotional exhaustion, overall fatigue, and sleep quality had further improved 12 weeks after the intervention. These improvements were not affected by the amount of exercise participants engaged in during the follow up period. This might be due to lack of variance in time spent on exercising, as most exercisers chose to engage in exercise after the intervention period (80%) on a regular basis (113.93 minutes [*SD*=88.51] a week).

Strengths, limitations, and suggestions for future research

We believe that a major strength of this study is its RCT-design, including longitudinal follow-up measures, and intention-to-treat analysis (Sibbald & Roland, 1998). Moreover, we used validated self-reports as well as objective cognitive performance measures, and we collected physiological data (physical fitness test) to obtain a more complete picture of the effects of the intervention. Future research may extend this approach by using other objective measures, such as sleep monitoring (Van de Water, Holmes & Hurley, 2011) or cortisol sampling (Oosterholt, Maes, Van der Linden, Verbraak & Kompier, 2015), to gain more in depth knowledge about the (psychophysiological) effects of exercise on study-related fatigue.

On a more practical note, another strength may well be our intervention program. We found that low intensity running three times a week had beneficial effects on various outcomes. Although it remains unknown whether this dose/type of exercise delivers optimal effects on the study outcomes, we showed that this intervention is at least feasible and accessible for university students with high levels of study-related fatigue, as dropout remained very low (i.e., 8% drop out rate) and compliance was high (i.e., 81% of running sessions was attended). Furthermore, a large majority of the students (i.e., 80%) chose to still engage in regular exercise in the 12 weeks after the intervention. It thus seems that this intervention has the potential to stimulate regular exercise patterns in the longer term. Future studies are recommended in which different exercise doses or types can be compared for investigating optimal effects on our outcomes. We believe that the exercise intensity in such studies should not be too high, as this may not or even negatively impact outcomes such as fatigue (Brooks & Carter, 2013), cognitive performance (Chang, Labban, Gapin & Etnier, 2012), and sleep quality (Driver & Taylor, 2000), especially in participants who are already fatigued at the start.

Apart from these strengths, several theoretical and methodological issues deserve discussion. These relate to the choice of employing a non-blinded wait-list design. As a result of using a wait list as control condition, we cannot rule out that the positive study findings are (partly) due to other ingredients of the intervention than exercise itself (i.e., non-specific factors), such as social support that may be provided in the group running sessions. Another consequence of this design is that we could not make firm conclusions about follow-up effects, as it was not possible to compare exercisers and controls in that period (i.e., controls received the exercise intervention after six weeks of waiting). Despite the limitations associated with a wait list design, we believe the choice for such a design is justified, because it is suitable for a first evaluation of a novel intervention (Mohr et al., 2009) and because a proven effective standard intervention to reduce study-related fatigue does not exist yet. Another potential limitation of the chosen design is lack of blinding, which may have enhanced the possibility that positive expectations of the participants influenced the results (Lindheimer, O'Connor & Dishman, 2015). It should be noted, though, that blinding of the participants was by definition not possible, because they received an 'active' intervention. Researchers and trainers in the current study were not blinded as well, since practical issues relating to the wait list design did not allow us to do so. However, as our measures did not involve subjective evaluations by the researchers involved in the study, we believe our study's findings were not biased by lack of blinding. We recommend that future randomized controlled trials employ a design and measurements that make it possible to further distillate whether specific (i.e., exercise) and/or non-specific factors (i.e., social support, placebo effect) of the intervention are responsible for the beneficial effects on study-related fatigue. For instance, a comparison between individual versus group exercise may reveal to what extent social support is responsible for positive effects.

Theoretical and practical contributions

We believe the results of the present study contribute to current evidence about exercise and study-related fatigue both theoretically and practically. With respect to theoretical contributions, we were among the first to investigate the association between exercise and study-related fatigue by using a strong methodological design. We showed that regular exercise at a low intensity has major benefits compared to time alone. Moreover, these effects did not fade away and persisted till at least twelve weeks after the intervention. Results found in this current study could form a basis for future studies investigating the working mechanisms of exercise on study-related fatigue and effectiveness studies that examine the effects of the intervention in daily practice.

With regard to practical contributions, we showed that exercise can effectively be applied as an intervention for student well-being. Furthermore, follow-up measures imply that the intervention has the potential to promote regular exercise and accompanying beneficial effects in the longer run. As exercise is accessible, simple, and inexpensive, this study offers practical suggestions for students and professionals who work with students.

Students experiencing fatigue problems should be supported and encouraged to engage in regular exercise, for instance by offering a university exercise programs like the exercise intervention under study.

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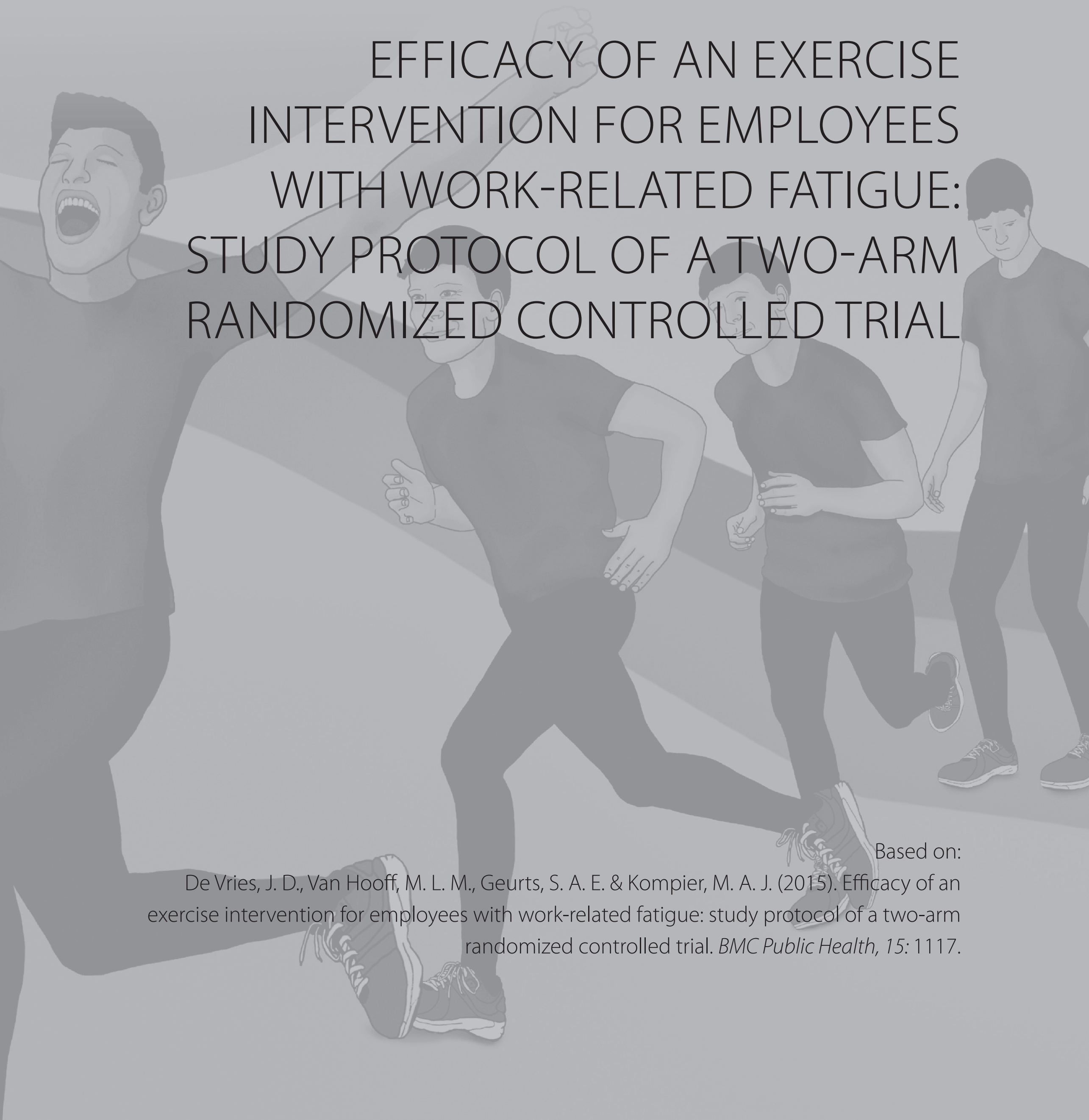
CHAPTER 3

EFFICACY OF AN EXERCISE INTERVENTION FOR EMPLOYEES WITH WORK-RELATED FATIGUE: STUDY PROTOCOL OF A TWO-ARM RANDOMIZED CONTROLLED TRIAL



Based on:
De Vries, J. D., Van Hooff, M. L. M., Geurts, S. A. E. & Kompier, M. A. J. (2015). Efficacy of an exercise intervention for employees with work-related fatigue: study protocol of a two-arm randomized controlled trial. *BMC Public Health, 15:* 1117.

Abstract

Purpose

The aim of the current study is to evaluate the efficacy of an exercise intervention to reduce work-related fatigue. Exercise is a potentially effective intervention strategy to reduce work-related fatigue, since it may enhance employees' ability to cope with work stress and it helps to detach from work. However, based on available research, no clear causal inferences regarding its efficacy can be made. This RCT therefore investigates whether exercise is effective in reducing work-related fatigue, and in improving other indicators of employees' mental and physical well-being and performance.

Methods

A two-arm parallel trial will be conducted. Participants (*N*=108) who experience high levels of work-related fatigue will be randomized at a 1:1 ratio to a 6-week exercise intervention or wait list (control). The exercise intervention consists of three one-hour low-intensity outdoor running sessions a week. Each week, two sessions take place in a group under supervision of a trainer, and one session is completed individually. The running sessions will be carried out during leisure time. The primary outcome is work-related fatigue. Secondary outcomes include work ability, self-efficacy, sleep quality, cognitive functioning, and aerobic fitness. These data will be collected at pre-intervention, post-intervention, and at 6 weeks and 12 weeks after the intervention. In addition, weekly measures of employees' well-being, and exercise activities (i.e. type, frequency, and duration) and experiences (i.e. pleasure, effort, and detachment) will be collected during the intervention period.

Discussion

This study will compare an exercise intervention to a wait list. This enables us to examine the effect of exercise on work-related fatigue compared to the natural course of these symptoms. As such, this study contributes to a better understanding of the causal link between exercise and work-related fatigue. If the intervention is proven effective, the results could provide a basis for future 'effectiveness' trials in which the (implementation of the) intervention can be investigated among a broader defined population in a less standardized way, eventually leading to better evidence-based policies and practices to employees, employers, health practitioners, and policy makers concerning the effect of exercise on work-related fatigue.

Background

Work-related fatigue is a global concern (estimated at 22% among employees in Europe; Eurofound, 2012) and is thought to at least partly result from prolonged stress at the work place (Maslach, Schaufeli & Leiter, 2001). Employees who experience work-related fatigue often have poorer work performance (Ricci, Chee, Lorandeau & Berger, 2007), are more frequently absent from work (Toppinen-Tanner, Ojajärvi, Väänänen, Kalimo & Jäppinen, 2005) and are at higher risk for ill health, such as cardiovascular diseases (Melamed, Shirom, Toker, Berliner & Shapira, 2006). If work-related fatigue becomes more severe, it can result in (long-term) clinical burnout (Maslach, Schaufeli & Leiter, 2001). Given the prevalence of work-related fatigue, and the negative impact on employees' work and health, it is valuable to examine potential intervention strategies to reduce these symptoms.

Regular exercise may be an eligible intervention strategy to reduce work-related fatigue. Assets of exercise include its accessibility, low costs (Lox, Martin Ginis & Petruzello, 2010), and positive side effects, such as reduced risk for cardiovascular diseases (Myers, 2003).

Exercise and work-related fatigue

The potential beneficial effects of exercise on work-related fatigue can be understood from a combination of various (interconnected) physiological and psychological mechanisms. For instance, it has been proposed that exercise enhances employees' ability to (physically and psychologically) cope with work stress (Rimmele et al., 2009; Yang et al., 2010). Others found that exercise helps to detach from work (Feuerhahn, Sonnentag & Woll, 2014), and enhances positive affect (Cooney et al., 2013), facilitating employees in replenishing their energy levels. In addition, research indicates that exercise impacts certain neural circuits and the release and uptake of chemicals in the brain, which are associated with better mental health (Dishman & O'Connor, 2009; Erickson, Gildengers & Butters, 2013).

Despite these proposed theoretical notions, based on available empirical evidence no clear causal inferences can be made about the effect of exercise on work-related fatigue. This is because knowledge about this relation is largely based on correlational studies (Ahola et al., 2012; Bernaards et al., 2006; De Vries et al., 2015; Lindwall, Gerber, Jonsdottir, Börjesson & Ahlborg, 2014; Gorter, Eijkman & Hoogstraten, 2000), and the relatively few available intervention studies suffered from one or more methodological shortcomings (Bretland & Thorsteinsson, 2014; Gerber et al., 2013; Härmä, Ilmarinen, Knauth, Rutenfranz & Hänninen, 1988; Tsai et al., 2013). In well-designed intervention studies, exercise was conducted among students (Puetz, Flowers & O'Connor, 2008; which leaves the question open whether results can be generalized to employees), or exercise was combined with other intervention ingredients (Van Rhenen, Blonk, Van der Klink, Van Dijk & Schaufeli, 2005; which makes it impossible to know to what extent the beneficial effects were due to exercise). Furthermore, research suggests that it may be more difficult for employees with high levels of work-related fatigue to engage in regular exercise (Ahola et al., 2012; De Vries et al., 2015; Gorter, Eijkman & Hoogstraten, 2000). Taken together, there is a need for methodologically sound intervention studies to better understand the causal link between exercise and work-related fatigue.

Against this background, the aim of the current study is to test the effect of exercise on work-related fatigue with a design that allows for strong causal inferences. To this end, employees with high levels of work-related fatigue who currently do not engage in regular exercise will be randomly assigned to either a six-week exercise intervention or a wait list (control group). This enables us to test the effect of exercise on work-related fatigue compared to the 'natural course' of these symptoms. In the intervention, we will use running as a form of exercise, because it is easy to implement: only running shoes are needed and it is high in flexibility in terms of time and place. Based on the proposed psychological and physiological working mechanisms and available empirical research, we hypothesize:

Hypothesis 1: the exercise intervention is effective in reducing work-related fatigue

Additionally, we will measure the impact of exercise on five secondary outcomes, which are relevant for employees with high levels of work-related fatigue, and which may be expected to be positively affected by means of regular exercise.

Exercise and self-efficacy

First of all, we will study the effect of exercise on work-related and general self-efficacy. It has been found that employees with high levels of work-related fatigue often experience reduced self-efficacy in their functioning at work (Maslach, Schaufeli & Leiter, 2001). On the other hand, it has been proposed that exercise is accompanied by a sense of mastery, which can increase self-efficacy with respect to exercise (McAuley & Blissmet, 2000), and other life domains (Craft, 2005). Since this current research is carried out in a work context, we will investigate whether exercise benefits work-related self-efficacy. We hypothesize:

Hypothesis 2a: the exercise intervention is effective in improving work-related self-efficacy among employees with high levels of work-related fatigue

As the sense of mastery gained by exercise may also be translated in a general confidence in succeeding at tasks and in situations (i.e. general self-efficacy), we expect:

Hypothesis 2b: the exercise intervention is effective in improving general self-efficacy among employees with high levels of work-related fatigue

Exercise and sleep

Second, we will study the impact of exercise on employees' sleep quality, and sleep duration. Sleep quality refers to 'how well someone sleeps', and is, for instance, characterized by the number of awakenings during the night and the degree of tiredness upon waking (Harvey, Stinson, Whitaker, Moskovitz & Virk, 2008). It has been found that work-related fatigue is negatively related to sleep quality (Ekstedt et al., 2006). Concurrently, previous studies have reported that regular exercise improves sleep quality (Kredlow, Capozzoli, Hearon, Calkins & Otto, 2015). In accordance with these empirical findings, we expect:

Hypothesis 2c: the exercise intervention is effective in improving sleep quality among employees with high levels of work-related fatigue

Research suggests that exercise may also impact employees' sleep duration (Kredlow, Capozzoli, Hearon, Calkins & Otto, 2015). Various pathways have been proposed to explain this relationship, such as cytokine concentration changes (for a review; see Buman & King, 2010). In agreement with these proposed mechanisms and empirical evidence, we expect:

Hypothesis 2d: the exercise intervention is effective in improving sleep duration among employees with high levels of work-related fatigue

Exercise and work ability

Third, we will investigate whether exercise benefits work ability. Work ability concerns the physical, psychological, and social capability of an employee to effectively cope with work demands (Tengland, 2010). It has been found that a high level of work-related fatigue is a risk factor for decreased work ability (Pranjic & Males-Bilic, 2014). As exercise contributes to psychological (Cooney et al., 2013), social (Eime, Young, Harvey, Charity & Payne, 2013), and physical health (Gerber & Pühse, 2009), it can be expected that exercise enhances employees' capacity to cope with work demands. Indeed, the scarce available empirical research shows that regular exercise is positively related to work ability (Arvidson, Börjesson, Ahlborg, Lindegård & Jonsdottir, 2013). Therefore, we expect:

Hypothesis 2e: the exercise intervention is effective in improving work ability among employees with high levels of work-related fatigue

Exercise and cognitive functioning

Fourth, the effect of exercise on cognitive functioning will be studied. Research shows that employees with high levels of work-related fatigue often display cognitive deficits, such as impaired executive functioning and cognitive problems in daily life (Oosterholt, Maes, Van der Linden, Verbraak & Kompier, 2012; Van der Linden, Keijsers, Eling & Schaijk, 2005). Executive functioning refers to a set of cognitive brain processes involving mental control and self-regulation (Alvarez & Emory, 2006). Evidence from a broad range of studies shows that exercise is linked to beneficial changes in cognitive functioning, in particular executive functions (Voss, Vivar, Kramer & Van Praag, 2013; Smith et al., 2010). Therefore, we hypothesize:

Hypothesis 2f: the exercise intervention is effective in improving cognitive functioning among employees with high levels of work-related fatigue

Exercise and aerobic fitness

Fifth, we will examine the effect of exercise on aerobic fitness. Aerobic fitness may be defined as the ability to deliver oxygen to the muscles and to utilize it to generate energy during exercise (Bouchard, Shephard & Stephens, 1994). Employees with high levels of work-related fatigue are found to have relatively low fitness levels (Gerber, Lindwall, Lindegård, Börjesson & Jonsdottir, 2013). On contrary, the evidence regarding the positive effects of exercise on fitness is overwhelming (Haskell et al., 2007), but effects also depend on the type, frequency, intensity, and duration of exercise (Garber et al., 2011). Because participants in our study will change from not exercising to regular (i.e. 3 times a week) exercising, we hypothesize:

Hypothesis 2g: the exercise intervention is effective in improving aerobic fitness among employees with high levels of work-related fatigue

For all primary and secondary outcomes (except cognitive functioning, due to possible learning effects), we will include follow-up measures to examine whether the proposed beneficial effects of exercise last over time.

Weekly trajectories of employee well-being

Next to measuring the effect of exercise on these primary and secondary outcomes after the intervention period, it is also valuable to examine employees' well-being trajectories during the intervention period. This prevents the intervention period of being a 'black box', in which it remains unknown which changes take place at what time. Therefore, in the current study, we will pay close attention to employee well-being during the intervention period. We will employ weekly self-administered single-item measures of fatigue, self-efficacy and sleep, which correspond to our primary and secondary outcomes. Additionally, we will investigate other single-item indicators of employee well-being, such as mood, to capture a broader range of the effects of the intervention. By doing so, we aim to provide a more fine-grained insight in how these different indicators of employee well-being develop during the intervention period, and whether weekly trajectories of these indicators differ between conditions. Although it is not possible to predict at what time these indicators change as a result from the intervention, we generally expect that:

Hypothesis 3: during the course of the intervention period, participants in the exercise condition show a larger improvement in weekly well-being compared to participants in the control condition

Compliance, and subjective exercise experiences as moderators of employee well-being

Finally, we will investigate possible moderators in the relation between exercise and employee well-being: compliance to the intervention and subjective exercise experiences. This could give us information for whom or under what conditions the intervention works best. Concerning compliance, we will measure participants' compliance with the running sessions of the exercise intervention. Participants who attend more of the running sessions of the intervention will likely also benefit more from the beneficial changes brought about by exercise. Therefore, we expect:

Hypothesis 4a: during the course of the intervention period participants with higher attendance rates show larger improvement in weekly well-being compared to participants with lower attendance rates

It has been argued that not only the type of activity (i.e. exercise) matters for beneficial effects on employee well-being, but that also the subjective experience of the activity is important (Demerouti, Bakker, Geurts & Taris, 2009; Van Hooff, Geurts, Beckers & Kompier, 2011). Therefore, we will pay attention to three ratings of employees' experiences (i.e. 'pleasure', 'detachment', and 'effort') during the running sessions, and examine how these experiences may or may not moderate exercise intervention efficacy. As research has shown that effects of activities, such as exercise, on well-being are stronger when these activities are enjoyed (Oerlemans, Bakker & Demerouti, 2014; Van Hooff, Geurts, Beckers & Kompier, 2011), we expect in this current study:

Hypothesis 4b: participants who rate their weekly running sessions as pleasant show a larger improvement in weekly well-being than participants who rate these sessions as less pleasant

Furthermore, as it has been found that employees who during activities experience psychological detachment from work (i.e. mentally distancing oneself from work), show better well-being outcomes (Demerouti, Bakker, Geurts & Taris, 2009), we hypothesize:

Hypothesis 4c: participants who psychologically detach from work during their weekly running sessions show a larger improvement in weekly well-being than participants who cannot psychologically detach from work during these sessions

For the experience of effort, it is difficult to formulate a hypothesis. Although exercise is an effortful activity in nature, research suggest that a too high intensity of exercise could lead to unbeneficial outcomes in well-being (Loy, O'Connor & Dishman, 2013). We will therefore investigate the experience of effort in relation to the weekly well-being outcomes in a more exploratory way.

Methods

Study design

The study design will be a two-arm parallel randomized controlled superiority trial. The effect of an exercise intervention on work-related fatigue will be compared to wait list. See Figure 3.1 for an overview of the study design.

Ethical issues

The research plan has been approved by the Ethics Committee Faculty of Social Sciences of the Radboud University (registration number: ECSW2015-1901-278). Informed consent for participation in the study will be obtained from all participants.

Participants and recruitment

Participants will be employees reporting high levels of work-related fatigue. Every employee – regardless job position – can sign up for participation. Participants will be recruited through advertisements with study information in personnel magazines, on facebook pages, and on intranet of large organizations in the region(s) in which the intervention will be carried out. Furthermore, advertisements and news items will be placed in (local) newspapers and on social media.

Inclusion criteria will be based on existing cut-off scores on two validated measures of work-related fatigue: a) ≥2.2 on the emotional exhaustion scale of the Dutch version of the Maslach Burnout Inventory (Schaufeli & Van Dierendonck, 2000); b) ≥22 on the Fatigue Assessment Scale (De Vries, Michielsen & Van Heck, 2003). Participants can fill out these two scales on the study website (www.runtervention.nl). When participants score high on both scales, the researcher (JdV) will ask these participants for further information about exclusion criteria by email. Exclusion criteria will be: a) ≥ one hour exercising a week; b) fatigue attributable to a medical condition; c) currently or in the past six months receiving psychological and/or pharmacological treatment; d) drug dependence; e) contraindications to exercise. Contraindications to exercise will be measured by the Physical Activity Readiness Questionnaire (PAR-Q; Thomas, Reading & Shephard, 1992). Eligible participants will be invited for an appointment with the first author (JdV) or research assistants. During this appointment, the baseline measures (T0; except for the two measures of work-related fatigue that are already filled out) will be completed, the cognitive performance tests will be done, and the randomization procedure will be carried out. A separate appointment will be planned for the aerobic fitness test.

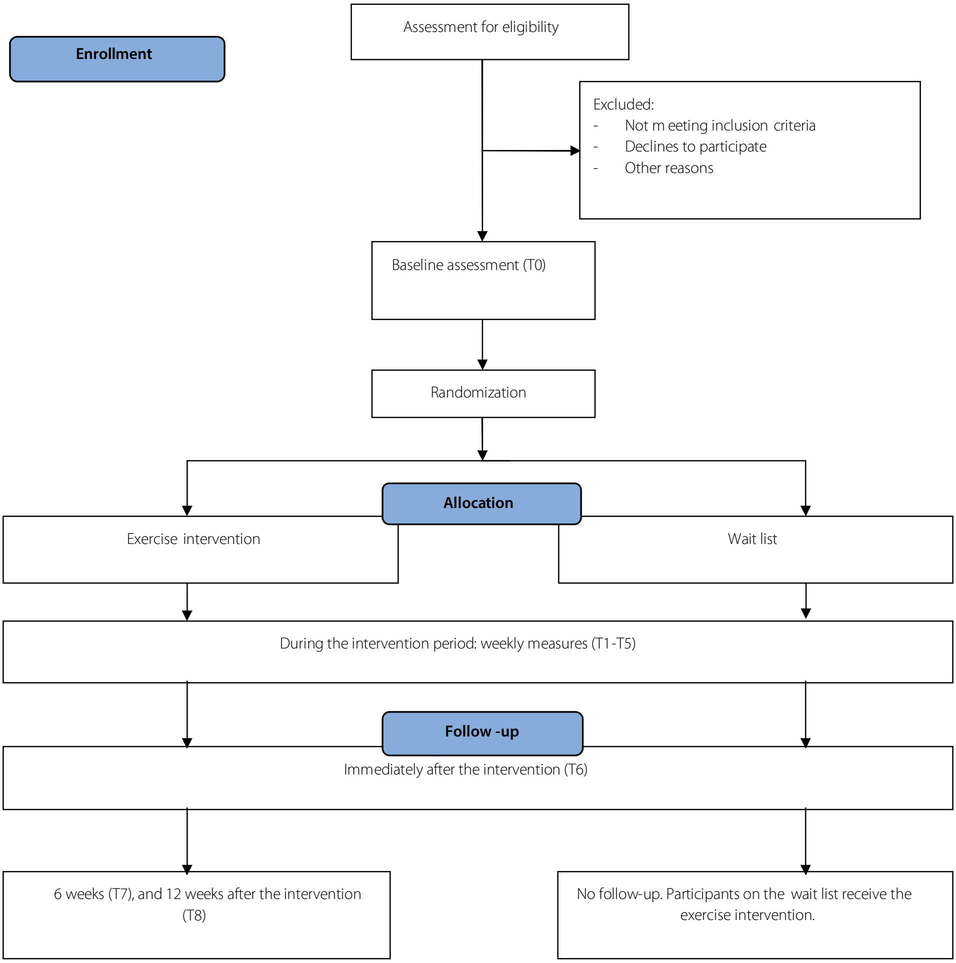


Figure 3.1. CONSORT Flow diagram.

Randomization and blinding

Participants will be randomly assigned to either an exercise condition or a wait list condition at a 1:1 ratio. Because the intention is to conduct the exercise intervention in groups of 10 participants, randomization will be based on a block size of 20. When the number of 20 eligible participants in a block is reached, participants in the exercise intervention condition start the intervention and the participants in the wait list condition remain on the wait list. The randomization procedure will be carried out after the participant has completed the baseline measurement (T0). The randomization procedure will be executed by the first author (JdV) or research assistant, using sealed opaque envelopes. The participant opens the envelope and tells the researcher to which condition (s)he has been assigned.

Conditions

Exercise intervention condition

The exercise intervention will take six consecutive weeks and comprises of low intensity running, meaning that participants should be able to talk while running (Persinger, Foster, Gibson, Fater & Porcari, 2004). This intensity is chosen, because research has indicated that a low intensity is effective in reducing fatigue (Loy, O'Connor & Dishman, 2013) and to reduce the risk of injuries (Woods, Bishop & Jones, 2007). Furthermore, the prospect of high intensity exercise may hamper participants' motivation to engage in or maintain exercise (Brewer, Manos, McDevitt, Cornelius & Van Raalte, 2000), especially when participants are already fatigued. In total, participants will run three times a week (18 running sessions in total): twice a week in a group of ten people guided by a running trainer, and once a week independently. Each running session lasts one hour, and consists of 15 minutes warming up, 30 minutes running alternated with walking, and 15 minutes cooling down. During the intervention, a fixed running schedule will be used in which the periods of running gradually increase, and the periods of walking gradually decrease. The goal is to achieve a 20 min period of continuous running in the last session. Each week, participants receive the running schedule of the upcoming week by email, as to know the content of the running sessions of that week beforehand. If participants miss a guided running session, they can catch up by doing an additional independent session in the same week that the guided session was originally planned. Participants will be advised to keep at least one rest day (i.e. no running session) in between the running sessions to reduce the risk of injuries (Hrjeljac, 2004).

Trainers of the exercise intervention will be experienced running trainers, additionally trained in the principles of 'running therapy', the most commonly applied form of exercise therapy for mental health problems in the Netherlands (Spijker et al., 2013; Running Therapy Foundation, 2009). Trainers will be instructed to watch participants' level of exertion during the running sessions and to urge participants to lower their speed if they are short of breath and not able to talk. Further, they will be instructed to ensure that the focus during the running sessions is not on 'performance' but rather on 'pleasure'.

Wait list condition

During the six-week exercise intervention condition, the participants in the wait list condition receive no intervention. After these six weeks, participants will receive the exercise intervention as well.

Measures

An overview of the measurement points of the primary outcome, secondary outcomes and weekly measures is given in Table 3.1. All measures, except for the cognitive performance tests and the aerobic fitness test, are self-administered (online questionnaires, sent by email). Completion of the self-administered questionnaires at T0, T6, T7, and T8 will take about 10 minutes. Participants in the wait list condition will complete the same measures as the participants in the exercise condition (T0-T6), except for the measures of subjective exercise experiences, compliance to the running sessions, and the follow-up measures at 6 and 12 weeks (T7 and T8).

Primary outcome measures

Work-related fatigue

We will use three self-reported indicators to measure work-related fatigue. First, *emotional exhaustion* will be assessed with the subscale 'Emotional exhaustion' of the Dutch adaptation of the Maslach Burnout Inventory (Maslach, Jackson & Leiter, 1996), the Utrecht Burnout Scale (UBOS; Schaufeli & Van Dierendonck, 2000). The scale consists of 5 items, for example "I feel burned out from my work" (0 = *never*, 6 = *every day*). A mean score equal to or higher than 2.2 on this scale is defined as a 'high level' of work-related fatigue (Schaufeli & Van Dierendonck, 2000). Previous research shows that psychometric properties of this scale are good (Roelofs, Verbraak, Keijsers, de Bruin & Schmidt, 2005). Secondly, *overall fatigue* will be measured with the 10-item Fatigue Assessment Scale (FAS; De Vries, Michielsen & Van Heck, 2003). An example question is "I get tired very quickly" (1 = *never*, 5 = *always*). A sum score higher than 21 is indicative of a high level of fatigue (De Vries, Michielsen, Van Heck & Drent, 2004). The scale has found to be valid and reliable (De Vries, Michielsen & Van Heck, 2003). Third, *need for recovery* will be assessed by a short version of the 'Need for Recovery Scale' (Van Veldhoven & Broersen, 2003). The scale consists of 6 items. An example item is: "Because of my job, at the end of the working day I feel rather exhausted" (1 = *(almost) never*, 4 = *(almost) always*). For this scale, no norm scores are available. Therefore, inclusion was based on the measures UBOS and FAS. Previous research shows that validity is good (De Vries, Michielsen & Van Heck, 2003).

Table 3.1. *Overview of the measurement points of the primary outcomes, secondary outcomes and weekly measures. (Table continues on next page)*

Construct	Pre intervention (T0)	During intervention (every week) (T1-T5)	Post intervention[a] (T6)	Follow-up after 6 weeks[b] (T7)	Follow-up after 12 weeks[b] T8)
Primary outcome					
Work-related fatigue:					
- Emotional exhaustion	✓		✓	✓	✓
- Need for Recovery	✓		✓	✓	✓
- Overall Fatigue	✓		✓	✓	✓
Secondary outcomes					
Sleep					
- Sleep quality	✓		✓	✓	✓
- Sleep duratio	✓		✓	✓	✓
Self-efficacy:					
- General self-efficacy	✓		✓	✓	✓
- Work self-efficacy	✓		✓	✓	✓
Work ability	✓		✓	✓	✓
Cognitive functioning:					
- Updating	✓		✓		
- Inhibition	✓		✓		
- Switching	✓		✓		
- Subjective costs of the tests	✓		✓		
- Cognitive Failures	✓		✓		
Aerobic fitness					
- VO_{2max}	✓		✓		
- Subjective costs of the test	✓		✓		
Weekly measures					
Employee well-being					
- Health	✓	✓✓✓✓✓	✓		
- Mood	✓	✓✓✓✓✓	✓		
- Fatigue	✓	✓✓✓✓✓	✓		
- Tension	✓	✓✓✓✓✓	✓		
- Stress	✓	✓✓✓✓✓	✓		
- Energy	✓	✓✓✓✓✓	✓		
- Satisfaction	✓	✓✓✓✓✓	✓		
- Irritation	✓	✓✓✓✓✓	✓		
- Sleep	✓	✓✓✓✓✓	✓		
- Self-efficacy (sport, work, private)	✓	✓✓✓✓✓	✓		

Table 3.1. *Overview of the measurement points of the primary outcomes, secondary outcomes and weekly measures. (Continued)*

Construct	Pre intervention (T0)	During intervention (every week) (T1-T5)	Post intervention[a] (T6)	Follow-up after 6 weeks[b] (T7)	Follow-up after 12 weeks[b] T8)
Exercise activities					
- Compliance to running sessions [a]		✓✓✓✓✓			
- (Other) exercise activities	✓	✓✓✓✓✓	✓	✓	✓
Subjective exercise experiences					
- Pleasure [a]		✓✓✓✓✓	✓		
- Effort [a]		✓✓✓✓✓	✓		
- Detachment [a]		✓✓✓✓✓	✓		

[a] Compliance to running sessions and subjective exercise experiences will be only collected among participants in the exercise condition, because participants in the control condition receive no running sessions during the intervention period.
[b] Follow-up measures will only be collected among participants in the exercise condition, because at the time of the follow-up measures the participants in the control condition receive the exercise intervention.

Secondary outcomes measures

Self-efficacy

We will use two indicators to measure self-efficacy. First, g*eneral self-efficacy* will be assessed using a Dutch translation of the 12-item General Self-Efficacy Scale (Bosscher & Smit, 1998). An example item is: "If I made a decision to do something, I will do it" (1= *strongly disagree*, 5 = *strongly agree*). Psychometric properties of this scale are good (Bosscher & Smit, 1998). Secondly, w*ork-related self-efficacy* will be measured by means of the subscale 'Competence' of the Utrecht Burnout Scale (Schaufeli & Van Dierendonck, 2000). An example item is: "If I make plans, I am convinced I will succeed in executing them" (0 = *never*, 6 = *every day*). Validity and reliability of the scale are good (Roelofs, Verbraak, Keijsers, de Bruin & Schmidt, 2005).

Sleep

To measure employees' *sleep quality*, the 6-item sleep quality scale of the Dutch Questionnaire on the Experience and Evaluation of work will be used (Van Veldhoven & Meijman, 1994). The scale measures the three main components of insomnia (i.e. difficulties in: initiating sleep, maintaining sleep, and restorative sleep) and overall sleep. An example item is: 'I often wake up several times during the night' (0 = *no,* 1 = *yes*). Furthermore, participants report their average sleep duration (hours, minutes) as an indicator of *sleep quantity*. Reliability and validity of the scale are found to be good (Van Veldhoven & Meijman, 1994).

Work ability will be measured by means of a single item (Ahlstrom, Grimby-Ekman, Hagberg & Dellve, 2010), namely "Can you indicate how you rate your current work ability when you compare it with your life-time best?" (0= *completely unable to work*, 10 = *work ability at its best*). This item has been shown to be a good alternative to more comprehensive measures of work ability (Ahlstrom, Grimby-Ekman, Hagberg & Dellve, 2010).

Cognitive functioning

Employees' cognitive functioning will be measured by means of four indicators: one self-report measure and three cognitive performance tests.

First, *self-reported cognitive problems* will be measured with a Dutch translation of the Cognitive Failure Questionnaire (CFQ; Broadbent, Cooper, FitzGerald & Parkes, 1982). This questionnaire measures the frequency of every day cognitive failures and consists of 25 items. An example question is: "Do you read something and find you have not been thinking about it and must read it again?" (1 = *never*, 5 = *very often*). Previous research shows that the CFQ has excellent psychometric properties (Bridger, Johnsen & Brasher, 2013).

Three types of executive functions (i.e. 'updating', 'switching', and 'inhibition'), which are considered as basic executive functions and can be clearly and precisely described (Miyake et al., 2000), will be measured with three validated tests. These tests will only be conducted pre (T0) and post (T6) intervention and not at follow up, because of possible learning effects. The tests will be provided in a counterbalanced order to the participants. However, for each participant the order of tests is similar pre and post intervention. Individual appointments in the lab of the university will be planned. Completion of the three cognitive tests, including filling out the subjective costs, takes about 30 minutes.

Updating will be measured with the 2-Back Task (Kirchner, 1958). Updating refers to the capability of actively manipulating relevant information in working memory (Miyake et al., 2000). During the task, 284 stimuli (the letters: b, d, g, p, t, and v) are displayed one by one in the centre of the screen. Each letter will be displayed for 450 ms, and the time between the letters will be 750 ms. The letters are presented in a quasi-randomly order in both capital and small letters. When the displayed letter is similar to the letter that is shown two screens before, participants have to push a button on a button-box (target rate: 32.5%). For a correct response, no distinction is made between capital and small letters. The number of correct responses will be taken as an indicator of updating.

Switching refers to the ability to shift between tasks (Miyake et al., 2000), and will be assessed by the Matching Task (Oosterholt, Van der Linden, Maes, Verbraak & Kompier, 2012; Poljac et al., 2010). In this task, four different geometric figures (a circle, a hexagon, a square, and a triangle), presented in the colors blue, green, red, or yellow are used as stimuli. The task consists of 31 task runs, each consisting of on average six trials (range: 4–8 trials). During a trial, a colored reference figure is displayed in the upper half of the screen, and four colored match figures are shown in the lower half of the screen. Participants will be instructed to match the reference figure to one of the match figures according to shape or color. Whether participants have to match according to shape or color, will be randomly chosen and indicated by a cue that is displayed for 1000 ms. Participants can push one of four buttons on the keyboard which corresponds to one of the four match figures in the lower half of the screen. During one single task run, participants have to match either according to color or shape. The color-shape combinations are shown in a way that there is one 'right' option. Half of all task runs consisted of 'switch' runs, in which the type of cue differs from the previous run. The other half consists of 'repetition' runs, in which the type of cue is identical to the previous run. The duration of the test is approximately six minutes. Both the mean reaction time for switch runs and repetition runs will be used as an outcome measure for switching (for more detailed information about this task, see Oosterholt, Van der Linden, Maes, Verbraak & Kompier, 2012).

Inhibition addresses one's capability to deliberately inhibit dominant and automatic responses to certain stressors (Miyake et al., 2000). Inhibition will be measured with the Sustained-Attention-to-Response Test (SART; Robertson, Manly, Andrade, Baddeley & Yiend, 1997). During this test, digits (ranging from 1–9) are displayed one-by-one in the centre of the screen. Participants are instructed to push a button on a button-box when a digit appears on the screen, except when the digit is a '3', which occurs in 11.1% of the cases. A total of 450 digits will be presented, each with a duration of 250 ms. The interval between digits is 850 ms. The number of inhibition errors (thus, when a participant presses the button when a '3' appears on the screen), will be taken as a measure for inhibition.

To obtain more insight into cognitive functioning, we will additionally evaluate the *subjective costs* (fatigue, motivation, demands, and effort) associated with doing these tests (Hockey, 2013; Meijman & Mulder, 1992). These *subjective costs* will be measured using single item measures, answered on a scale from 1 (*not at all*) to 10 (*very much*). Before doing the cognitive tests, participants will rate how motivated they are to do the tests. Fatigue will be measured prior to and after the tests. In addition, after each cognitive test, participants will be asked to score how demanding the test had been. After completing all the tests, participants indicate how much effort they spent when doing the tests.

Aerobic fitness

We will measure aerobic fitness using the estimated maximal oxygen uptake (VO_{2max}), obtained from the UKK walk test (Oja, Laukkanen, Pasanen, Tyry & Vuori, 1991). This test has found to be valid and feasible for a healthy adult population (Oja, Laukkanen, Pasanen, Tyry & Vuori, 1991). During this test, participants have to walk 2 kilometer as fast as possible. The test will take place on a 400m outdoor track in groups of (maximum) ten participants. Participants start individually every 30s. The instruction is as follows: "Walk the distance as fast as you can, but do not risk your health". Immediately after the walk, the heart rate and walking time will be measured. The variables used to calculate VO_{2max} are walking time, heart rate, body weight, height, and gender (see Oja, Laukkanen, Pasanen, Tyry & Vuori [1991] for exact equations).

We will also measure participants' *subjective costs* of doing the UKK walk test. The questions used for this purpose are similar to those asked before and after the cognitive tasks, except that we add another question about how 'short of breath' participants are immediately after the test. Completion of the test, including filling out the items about subjective costs, takes about 25 minutes.

Weekly measures during the intervention period

During the six weeks of the intervention period, each Wednesday all participants (intervention and control condition) will be requested to complete a short questionnaire that will be sent by email. Completion of the weekly measures takes five minutes.

Employee well-being

We will use twelve single-item measures as indicators of employees' *weekly well-being* in order to obtain a detailed account of the course of these indicators during the intervention period. Single item measures are chosen because such measures require minimum effort to complete, and because they have been found to be valid indicators of employee well-being (Van Hooff, Geurts, Kompier & Taris, 2007). The items are introduced as follows: "Can you indicate with a report mark between 1 (*not at all applicable*) to 10 (*extremely applicable*) to what extent the following state of minds were applicable to you during the previous two days?" The items are: "healthy", "tired", "tense", "happy", "satisfied", "energetic", "stressed", "vital", and "irritated". The response scale from 1 to 10 is based on the typical Dutch grade notation system.

Additionally, three single item measures to assess participants' *weekly self-efficacy* regarding exercise, work, and other private personal goals will be as follows: "Can you indicate with a report mark between 1 (*not at all certain*) to 10 (*extremely certain*) how certain you are that you can reach your goals regarding "exercise", "work", "other private personal goals" during the previous two days?

Furthermore, to measure employees' *weekly sleep quality*, the 6-item sleep quality scale derived from the Dutch Questionnaire on the Experience and Evaluation of work will be used (Van Veldhoven & Meijman, 1994). As these items were originally developed for chronic sleep complaints, the scale is adapted for weekly measurement. An example item is: 'I slept well last week' (reversed; 1= *yes*, 0 = *no*). Next to sleep quality, also the mean hours sleep a night will be assessed (i.e. '*sleep quantity*').

Exercise activities

Each week, participants' exercise and physical activity levels will be assessed. Participants in the exercise condition are requested to indicate their *compliance* to the guided and individual running sessions. Additionally, if applicable, they are asked to indicate whether they performed a missed guided running session on their own, and whether they performed this session according to the fixed running schedule or not. Besides that, they are requested to indicate if they performed *other exercise activities* than running during the past week (type, duration, and frequency). Participants in the control condition will be asked to indicate whether they engaged in exercise activities during the past week (type, duration, and frequency). Finally, all participants are requested to report their *physical activity* during the past week: 'On how many days a week were you physically active during at least 30 minutes a day (only count physical activity that is equally demanding as brisk walking or biking. Activities shorter than ten minutes do not count) – during your work and free time together?' (*0-7 days*) (WHO, 2010).

Subjective exercise experiences

To measure how participants in the exercise intervention experience the running sessions, we will administer single-item measures about *pleasure* and *effort*. The items are introduced as follows: "Can you indicate with a report mark between 1 (not at all applicable) to 10 (extremely applicable) how you experienced last week's running sessions?" Separate ratings will be collected for the guided and individual running sessions. Additionally, the extent to which employees can 'unwind' from work during the running sessions will be measured using an adapted version of the 4-item *psychological detachment* scale of the Recovery Experience Questionnaire (Sonnentag & Fritz, 2007). An example item is: 'Last week, I forgot about work during the running sessions'. Previous research shows that psychometric properties are good (Sonnentag & Fritz, 2007).

Statistical analyses

Sample size

Based on previous research, it is difficult to predict an exact effect size on which we can base our sample size, given that these studies report small to large effect sizes (Bretland & Thorsteinsson, 2014, Gerber et al., 2013; Puetz, Flowers & O'Connor, 2008; Tsai et al., 2013), and that they differ in design (i.e., duration of exercise intervention; absence of control condition) and target audience (i.e., low to clinical levels of work-related fatigue). Since we conduct our study among employees with high but no clinical levels of work-related fatigue (we expect a decrease in work-related fatigue, but not as large as we would expect among employees with clinical levels) and our intervention is relatively short, we expect a small to medium effect size. To determine sample size, a power analysis has been conducted in the statistical program G*power (Faul, Erdfelder, Lang & Buchner, 2007). This analysis was based on a repeated measures ANOVA with work-related fatigue as within subjects factors and condition as between subjects factor. This analysis showed that a total of 90 participants was required in order to detect a small to medium effect of .15 on the primary outcome work-related fatigue from pre to post intervention, given a two-sided 5% significance level, a power of 80%, and an correlation of .50 across repeated measures (Toppinen-Tanner, Kalimo & Mutanen, 2002). Because we anticipated a dropout rate of about 20%, we intend to recruit 108 participants.

Analyses of primary and secondary outcomes

We will use intention-to-treat analysis, meaning that all participants who are randomized to a condition will be included in the analyses. To test the efficacy of the exercise intervention (i.e. change in primary and secondary outcomes from pre [T0] to post [T6]), we will perform 2x2 repeated measures (M)ANOVAs with condition (exercise versus wait list) as between-subjects factor, and time (pre [T0] versus post [T6]) as within-subjects factor. We will conduct a RM-MANOVA for the three indicators of work-related fatigue together (*Hypothesis 1*). Furthermore, we will conduct separate RM-(M)ANOVAs for respectively self-efficacy (*Hypothesis 2a and 2b*), sleep (*Hypothesis 2c and 2d*), work ability (*Hypothesis 2e*), cognitive functioning (*Hypothesis 2f*), and aerobic fitness (*Hypothesis 2g*). The Matching Task will be analyzed using a 2x2x2 mixed design ANOVA, with 'run type' (switch versus repetition), and time (pre versus post) as within-subjects factors, and condition as between-subjects factor (exercise versus wait list). In all analyses, we are particularly interested in the 'condition x time' interaction, because this indicates that the conditions differ from each other with respect to the development of the outcome measure over time. If applicable, significant interactions will be further examined by paired-sample t-tests. Partial eta-squared (η^2) will be reported as effect size.

Additionally, to obtain more thorough insight into the clinical meaningfulness of the changes brought about by the exercise intervention (Jacobson & Truax, 1991), we will perform a Chi-Square Test to see if the number of participants who score below cut-off scores of fatigue after the intervention period (T6) differs between the intervention and the control condition (emotional exhaustion <2.2 on the UBOS; overall fatigue: <22 on the FAS).

To investigate whether intervention-effects last during the follow-up period, for each primary and secondary outcome measure, a repeated measures MANOVA will be performed to see whether it differs between pre (T0), post (T6), 6 weeks after the intervention period (T7), and 12 weeks after the intervention period (T8). If the overall time effect of MANOVA is significant, post hoc tests will be carried out to exactly determine between what time points the outcome had changed. As follow-up measures are only available for the intervention condition, the control condition will not be included in these analyses.

Analyses of weekly trajectories of employee well-being

The trajectories of employees' weekly well-being during the intervention period will be analyzed using growth models in a multilevel modeling framework, because our weekly occasions (level 1) are nested within persons (level 2). This analyzing method allows us to estimate inter-individual as well as intra-individual patters of change over time in a powerful way (Hox, 2010). The data will be analyzed using MPlus (Muthén & Muthén, 2010). For each of the weekly indicators of employee well-being, a model will be tested. This model consists of an intercept term, and variances at the occasion and person level. Furthermore, 'time' (7 occasions: T0 to T6) will be added as a random factor to the model (to measure the rate of change per unit of time), as well as 'time^2' (to measure a change in the rate of growth). Additionally, 'condition' (0= control, 1= exercise) will be added as a fixed factor to the model, and will interact with 'time', and 'time^2'. As such, it will be investigated whether there is an effect of exercise on the rate of change in well-being over time.

Analyses of moderators

To assess to what extent the exercise experiences ('pleasure', 'detachment', 'effort') and compliance (number of attended running sessions) of participants in the exercise condition moderate the weekly outcomes of employee well-being, we will also use a multilevel modeling framework performed in MPlus (Muthén & Muthén, 2010). For each indicator of employee well-being in relation to the exercise experiences and attendance rate, we test a model. This model is equivalent to our first model, except that condition is not a predictor anymore (because only participants in the exercise intervention are studied), and the three exercise experiences and compliance are added as fixed covariates in the model and interact with 'time', and 'time^2'.

Discussion

This article describes the design of a two-arm RCT to evaluate the efficacy of an exercise intervention on work-related fatigue. Except for work-related fatigue, the effect of exercise on five secondary outcomes related to work-related fatigue will be studied. Furthermore, we will gain insight in how different indicators of employees' well-being develop during the intervention period. This will inform us if, and if so, at what point in time the intervention is effective in changing these indicators. Furthermore, we also examine participants' experiences of and the attendance to the running sessions of the exercise intervention to get a better understanding of the extent to which these experiences and activities may have differential effects on intervention efficacy.

Since we wish to investigate the effect of exercise compared to the natural course of work-related fatigue over time, and there is no standard effective intervention for work-related fatigue available yet, we choose for a wait list as control condition. To overcome possible ethical and practical concerns of wait lists in randomized controlled trials (Millum & Grady, 2013), we decide to employ the duration of a relatively short exercise intervention (i.e. six weeks). It could be imagined that withholding an intervention from employees with high levels of work-related fatigue for a longer period of time could worsen their problems. Furthermore, a longer waiting period for the participants in the control condition could result in higher attrition rates.

Strengths and limitations

The main strength of this study is its methodological quality: the use of the randomized controlled design, intention-to-treat analysis, follow-up measures, and multi-method measures (self-reports and performance measures). Using these design elements reduces several sources of bias, like selection bias, withdrawal bias, and allows us to make strong causal inferences (Schulz, Altman & Moher, 2010). As such, the current RCT will add to the existing scientific literature about the effect of exercise on work-related fatigue. Since our intervention will be delivered in a uniform fashion to a specific homogeneous target audience, and thus can be regarded as an 'efficacy trial' (i.e., the intervention produces the expected result under ideal circumstances), the results of the current study may also provide a basis for future 'effectiveness' trials in which the (implementation of the) intervention can be investigated among a broader defined population in a less standardized way (Glasgow, Lichtenstein & Marcus, 2003).

Another strength is our sample. We choose to investigate employees who are still able to work, but have (relatively) high levels of work-related fatigue. As such, our intervention can be regarded as secondary prevention (Tetrick & Quick, 2003). We expect that exercise not only reduces work-related fatigue symptoms, but also prevents these from becoming more severe (i.e. clinical burnout; Roelofs, Verbraak, Keijsers, de Bruin & Schidt, 2005). We believe that it is valuable to target these employees, because prevention is better than cure. However, future research could also investigate whether exercise benefits clinical burnout.
Despite its strengths, several issues concerning our study deserve attention. First, our study is not blinded, because active participation of the participants and trainers is necessary in our intervention. Furthermore, because the number and timing of outcome measures differed between the intervention and the control group, it was not possible for researchers involved in this study to be blind to the condition they were assessing. Although blinding is preferable, it should be noted that our primary and secondary outcomes require no subjective evaluation from the outcome assessors. As such, we argue that this issue is of limited influence (Wood et al., 2008).

Additionally, the fact that the control group in the current study is on a wait list needs attention. Although a wait list condition is – given our research aims and current evidence about effective interventions for work-related fatigue – the best option, it has been argued that wait list groups are not truly untreated because they are contacted, consented, randomized, and measured (McCambridge, Kypri & Elbourne, 2014). This might cause a decrease in symptoms while not receiving an 'active' intervention. Following this reasoning, the effects that may be found in this study may be underestimations of the true causal effects.

Lastly, we will not use objective measures to watch participants' exercise intensity (e.g. heart rate monitoring), although these measures provide the most accurate estimate of participants' exercise intensity. However, it has been shown that being able to talk is well correlated with heart rates that match low intensity (Persinger, Foster, Gibson, Fater & Porcari, 2004), suggesting that it is an effective tool to monitor exercise intensity. Furthermore, the trainers are instructed to watch participants' intensity, by making sure they can still talk while running. To control whether the running was not too intensive, we will ask participants about their perceived exertion during the running sessions. Although this is a subjective measure, it provides a fairly good estimate of the actual spent effort during physical activity (Borg, 1998).

Implications for practice

This RCT is relevant, because work-related fatigue is prevalent among employees and it negatively impacts employees' health and work performance. If the intervention is proven effective, this would suggest that there is a relatively simple, inexpensive and accessible intervention strategy to reduce work-related fatigue. The results of this RCT could be used to provide better evidence-based policies and practices to employees, employers, health practitioners, and policy makers concerning the effect of exercise on employee well-being.

Conclusion

This RCT has the ability to make a contribution to the evidence base for the effect of exercise on work-related fatigue.

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CHAPTER 4

EXERCISE TO REDUCE WORK-RELATED FATIGUE AMONG EMPLOYEES: A RANDOMIZED CONTROLLED TRIAL

Based on:
De Vries, J. D., Van Hooff, M. L. M., Geurts, S. A. E. & Kompier, M. A. J. (2017). Exercise to reduce work-related fatigue among employees: a randomized controlled trial. *Scandinavian Journal of Work, Environment and Health, 43, 337-349*

Abstract

Purpose

The present study evaluated the efficacy of an exercise intervention to reduce work-related fatigue (emotional exhaustion, overall fatigue and need for recovery). The effects of exercise on self-efficacy, sleep, work ability, cognitive functioning and aerobic fitness (secondary outcomes) were also investigated.

Methods

Employees with high levels of work-related fatigue were randomly assigned to either a six-week exercise intervention (EI; *N* = 49) or a wait list control group (WLC; *N* = 47). All participants were measured pre- (T0) and post-intervention (T1). EI participants were also measured 6 (T2) and 12 weeks (T3) after the end of the intervention. Analyses were based on intention-to-treat (ITT) and per-protocol (PP). PP-analyses only included EI participants (*n* = 31) who completed the intervention and WLC participants (*n* = 35) who did not increase their exercise level during the wait period.

Results

Analyses of covariance (ANCOVA) revealed that at T1 the EI group reported lower emotional exhaustion and overall fatigue than the WLC group, however, only according to PP-analyses. Both according to ITT- and PP-analyses, EI participants showed higher sleep quality, work ability and self-reported cognitive functioning at T1 compared to WLC participants. Intervention effects were maintained at T2 and T3.

Conclusion

The exercise intervention had enduring effects on work-related fatigue and on broader indicators of employee well-being. This study demonstrates that in case of work-related fatigue, exercise does constitute a powerful medicine for those who comply to the treatment.

Introduction

Many employees experience work-related fatigue (estimated at 22%; Eurofound, 2012; Ricci, Chee, Lorandeau & Berger, 2007). Its more extreme manifestation, 'burnout' is, at least partly, the result of prolonged work-related stress, resulting from excessive workload, time pressure, or organizational change (Maslach, Schaufeli & Leiter, 2001; Techera, Hallowell, Stambaugh & Littlejohn, 2016). Negative consequences for employees include impaired cognitive functioning, reduced productivity at work, and health problems such as depression and cardiovascular diseases (Deligkaris, Panagopoulou, Montgomery & Masoura, 2014; Melamed, Shirom, Toker, Berliner & Shapira, 2006; Techera, Hallowell, Stambaugh & Littlejohn, 2016). These negative consequences have prompted calls for effective interventions to reduce work-related fatigue. In the current study, exercise as a potential intervention to reduce work-related fatigue is investigated.

It has been proposed that a combination of psychological and physiological mechanisms underlies the beneficial effect of exercise on work-related fatigue. As regards the first, exercise may help employees to psychologically detach from work (Feuerhahn, Sonnentag & Woll, 2014; Ten Brummerlhuis & Bakker, 2012) and in this way prevent prolonged stress responses that may result in enduring fatigue (Sonnentag, 2012). As regards the second, increased physical fitness may promote stress resilience through faster stress recovery (Klaperski, Van Dawans, Heinrichs & Fuchs, 2014) thus reducing the risk of persistent fatigue. So far, only few studies have examined the effect of exercise on work-related fatigue. Cross-sectional and longitudinal studies have reported an inverse relationship between the two (Ahola et al., 2012; Bernaards et al., 2006; Jonsdottir, Rödjer, Hadzibajramovic, Börjesson & Ahlborg, 2010; Lindwall, Gerber, Jonsdotir, Börjesson & Ahlborg, 2014), and the few available intervention studies show beneficial effects of exercise on work-related fatigue (Bretland & Thorsteinsson, 2014; Freitas, Carneseca, Paiva & Paiva, 2014; Gerber et al., 2013; Tsai et al., 2013; Van Rhenen, Blonk, Van der Klink, Van Dijk & Schaufeli, 2005). However, these intervention studies suffered from one or more methodological shortcomings, such as no adequate control condition, no (described) randomization procedure, and lack of non-response and intention-to-treat analyses. Due to these shortcomings, the causality of the association between exercise and work-related fatigue remains largely unclear.

Therefore, the aim of the current study was to uncover the causal association between exercise and work-related fatigue by employing a randomized controlled trial. To this end, we selected employees with high levels of work-related fatigue and randomly assigned them to either a six-week exercise intervention (EI) or a wait list control group (WLC). As such, it was investigated whether exercise has beneficial effects on work-related fatigue compared to the natural course of these symptoms. It was hypothesized that exercise reduces work-related fatigue. Additionally, we aimed to investigate the effect of exercise on five secondary outcomes of employee well-being: self-efficacy, sleep, work ability, cognitive functioning, and aerobic fitness. Prior work shows that fatigued employees often show deficiencies in these outcomes (Ekstedt et al., 2006; Gerber, Lindwall, Lindegård, Börjesson & Jonsdottir, 2013; Oosterholt, Van der Linden, Maes, Verbraak & Kompier, 2012; Prjanjic & Males-Billic, 2014), while it has been suggested that exercise positively affects them (Arvidson, Börjesson , Ahlborg, Lindegård & Jonsdottir, 2013; Bouchard, Shephard & Stephans, 1994, Craft, 2005, Kredlow, Capozzoli, Hearon, Calkins & Otto, 2015; Smith et al., 2010, see De Vries, Van Hooff, Geurts & Kompier [2015] for a more extensive justification for the choice of secondary outcomes). We therefore expected that exercise improves general and work-related self-efficacy, sleep quality and quantity, work ability, cognitive functioning, and aerobic fitness.

Methods

Study design

It was investigated whether the exercise intervention group (EI) group was superior to the wait list control group (WLC) with respect to the reduction of work-related fatigue. Participants were randomly allocated to one of the two conditions at a ratio of 1:1 and a block size of 20. A full description of the study protocol has been previously published (De Vries, Van Hooff, Geurts & Kompier, 2015). The study protocol was approved by Ethics Committee of the Faculty of Social Sciences of the Radboud University (registration number: ECSW2015-1901-278) and preregistered at the Netherlands Trial Register (NTR5034).

Participants and procedure

Participants were recruited via advertisements in newspapers, on social media, and on the intranet of large health care organizations. They were eligible to participate if they were currently employed and had high levels of work-related fatigue, as indicated by a high score on two validated questionnaires (i.e., ≥2.2 on the emotional exhaustion scale of the Utrecht Burnout Scale [Schaufeli & Van Dierendonck, 2000], and ≥22 on the Fatigue Assessment Scale [De Vries, Michielsen & Van Heck, 2003]). Exclusion criteria were a) ≥ one hour exercising a week; b) fatigue attributable to a medical condition; c) currently or in the past six months receiving psychological and/or pharmacological treatment; d) drug dependence; e) contra-indications to exercise. The latter were measured with the Physical Activity Readiness Questionnaire (Thomas, Reading & Shephard, 1992). Sample size calculation can be found in the study protocol (De Vries, Van Hooff, Geurts & Kompier, 2015). In total, 362 employees were screened for eligibility (see Figure 4.1). Of these, 96 were eligible and willing to participate. After baseline assessment randomization was carried out by the first author (JdV) or a research assistant, using sealed opaque envelopes.

Exercise intervention

The exercise intervention consisted of one-hour low-intensity running sessions three times a week for a period of six consecutive weeks. Two running sessions were carried out in a small group of 10 participants, led by a licensed running trainer, and one running session was carried out independently by the participant. More details of the intervention can be found elsewhere (De Vries, Van Hooff, Geurts & Kompier, 2015).

WLC participants were offered to follow the intervention after six weeks of waiting. Thirty-nine of 47 WLC participants actually followed the intervention.

Measures

All outcomes were measured among EI and WLC participants at pre- (T0) and post-intervention (T1). EI participants were also measured at follow-up: six weeks (T2) and twelve weeks (T3) after the intervention period. We used self-reported data, and 'objective' tests of cognitive performance and aerobic fitness. Cognitive functioning and aerobic fitness were not measured at follow-up. Materials are presented shortly. Full details of the materials can be found in the study protocol (De Vries, Van Hooff, Geurts & Kompier, 2015).

Primary outcome

Work-related fatigue

Work-related fatigue was measured with three indicators representing slightly different aspects of the concept. *Emotional exhaustion* represents serious (long-term) fatigue as a consequence of chronic job stress (Maslach, Schaufeli & Leiter, 2001). It was measured with the 5-item 'Emotional exhaustion' scale of the Dutch adaptation of the Maslach Burnout Inventory (Maslach, Jackson & Leiter, 1996): the Utrecht Burnout Scale (UBOS; Schaufeli & Van Dierendonck, 2000). Example item: "I feel burned out from my work" (0 = *never*, 6 = *every day*). Cronbach's alpha was .80 at T0, .91 at T1, .94 at T2, and .90 at T3. A mean score ≥2.2 was considered as 'high' work-related fatigue (Schaufeli & Van Dierendonck, 2000). *Overall fatigue* represents general mental and physical fatigue (De Vries, Michielsen & Van Heck, 2003). It was measured with the 10-item Fatigue Assessment Scale, a valid questionnaire to measure fatigue in the working population (FAS; De Vries, Michielsen & Van Heck, 2003). Example item: "I get tired very quickly" (1 = *never*, 5 = *always*). Cronbach's alpha was .84 at T0, .88 at T1, .88 at T2, and .82 at T3. A sum score ≥22 signifies 'high' overall fatigue (De Vries, Michielsen & Van Heck, 2003). *Need for Recovery* is meant to represent short-term work-related fatigue (Van Veldhoven & Broersen, 2003). Conceptually, it bridges the stage between fatigue that occurs after one effortful workday and serious long-term work-related fatigue, such as burnout (Van Veldhoven & Broersen, 2003). It was assessed by the short version of the Need for Recovery Scale, including 6 items (Van Veldhoven & Broersen, 2003;

Van Veldhoven, Prins, Van der Laken & Dijkstra, 2015). Example item: "Because of my job, at the end of the working day I feel rather exhausted" (1= *(almost) never*, 4 = *(almost) always*). A mean score was computed. Cronbach's alpha was .85 at T0, .89 at T1, .87 at T2, and .90 at T3.

Secondary outcomes

Sleep

Poor sleep quality was measured with the 6-item sleep quality scale of the Dutch Questionnaire on the Experience and Evaluation of work (Van Veldhoven, Prins, Van der Laken & Dijkstra, 2015). A higher sum score indicates poorer sleep quality. Example item: "I often wake up several times during the night' (0 = *no*, 1= *yes*). Cronbach's alpha was .62 at T0, .65 at T1, .71 at T2, and .68 at T3. *Sleep quantity* was assessed by questioning employees' average hours and minutes of sleep.

Self-efficacy

General self-efficacy was assessed by the Dutch version of the 12-item General Self-Efficacy Scale (Bosscher & Smit, 1998). Example item: "If I made a decision to do something, I will do it" (1 = *strongly disagree*, 5 = *strongly agree*). Cronbach's alphas were .84 at T0, .87 at T1, .84 at T2, and .84 at T3. *Work-related self-efficacy* was measured with the subscale 'Competence' of the Utrecht Burnout Scale (Schaufeli & Van Dierendonck, 2000). Example item: "If I make plans, I am convinced I will succeed in executing them" (0 = *never*, 6 = *every day*). Cronbach's alphas were .81 at T0, .85 at T1, .90 at T2, and .89 at T3.

Work ability

Work ability was measured by means of a single-item (Ahlstrom, Grimby-Ekman, Hagberg & Dellve, 2010; El Fassi et al., 2013): "Can you indicate how you rate your current work ability when you compare it with your lifetime best?" (0 = *completely unable to work*, 10 = *work ability at its best*).

Cognitive functioning

Four indicators were used to measure participants' cognitive functioning. *Self-reported cognitive functioning* was assessed by the 25-item Dutch version of the Cognitive Failures Questionnaire (Broadbent, Cooper, FitzGerald & Parkes, 1982). Example item: "Do you read something and find you have not been thinking about it and must read it again?" (1 = *never*, 5 = *very often*). Cronbach's alpha was .90 at T0, and .90 at T1. A sum score was computed, higher scores indicating lower cognitive functioning. Three types of executive functions (i.e. '*updating*', '*switching*', and '*inhibition*') were measured by means of cognitive performance tests. *Updating* (Miyake et al., 2000) was measured with the 2-Back Task (Kirchner, 1958).

During the task, 284 letters were presented one by one on the screen. When the displayed letter was similar to the letter that was shown two screens before, participants had to push a button (i.e., correct response). Performance was measured by the number of correct responses. *Switching* was measured with the Matching Task (Oosterholt, Van der Linden, Maes, Verbraak & Kompier, 2012; Poljac et al., 2010). The task consisted of 31 task runs, each consisting of 4-8 trials. In the trials participants had to match several colored figures to each other according to shape or color (as indicated by a 'cue' before each task run). Half of all task runs consisted of 'switch' runs, in which the type of cue differed from the previous run. The other half consisted of 'repetition' runs, in which the type of cue was identical to the previous run. Switch cost (i.e., the difference in reaction time to switch and repetition runs) was used as an indicator of cognitive performance. *Inhibition* was measured with the Sustained-Attention-to-Response Test (SART; Robertson, Manly, Andrade, Baddeley & Yiend, 1997). Digits were presented on a screen and participants had to push a button as fast as possible, except when the digit was '3'. The number of correct inhibitions (i.e., not pressing the button when '3' appeared) was taken as a measure for cognitive performance. To obtain a more thorough insight in cognitive functioning, the subjective costs (fatigue, motivation, demands and effort) associated with doing the cognitive performance tests were evaluated. These subjective costs were measured using single item measures, answered on a 10-point scale from 1 (*not at all*) to 10 (*very much*).

Aerobic fitness

VO_{2max} was used as an indicator of aerobic fitness. It was obtained from the UKK walk test, a simple and valid method to measure aerobic fitness (Oja, Laukkanen, Pasanen, Tyry & Vuori, 1991). Participants needed to walk 2km as fast as possible. Based on heart rate, walking time, body weight, height, and gender, VO_{2max} was estimated (Oja, Laukkanen, Pasanen, Tyry & Vuori, 1991). Higher VO_{2max} indicates a better aerobic fitness level. Subjective costs of doing the UKK walk test were also assessed. Items used to this purpose were similar to those questioned before and after the cognitive performance tests, except that another item was added about how 'short of breath' participants were immediately after the test.

Exercise activities

During each week of the intervention period, EI participants were asked to indicate their compliance to the guided and individual exercise sessions. At T2 and T3, they were asked whether they engaged in regular exercise during the last six weeks (type, frequency, duration). WLC participants were also asked to indicate whether they engaged in regular exercise during each week of the intervention period (type, duration, and frequency).

Statistical analysis

Results with respect to pre- and post-comparisons of primary and secondary outcomes were based on the intention-to-treat (ITT), and the per-protocol (PP) principle (Ten Have, Normands, Marcus, Brown & Lacori, 2010). ITT is a strategy for the analysis of RCTs that compares participants in the conditions to which they are originally randomly assigned, irrespective of dropout, non-compliance or anything that happens after randomization (Ten Have, Normands, Marcus, Brown & Lacori, 2010). Thus, all participants who are randomized are analyzed. The ITT strategy has two main purposes: i) it maintains intervention groups that are similar apart from random variation. If analyses are not performed on the groups produced by randomization, the principle of randomization is lost; ii) it reflects an effect estimate of the intervention that would have been observed in practice, since dropout and non-compliance is also common in practice. ITT therefore reflects an estimate of the 'effectiveness' of the intervention (i.e., the working of the intervention in practice). The PP strategy excludes participants who deviated from the protocol (Ten Have, Normands, Marcus, Brown & Lacori, 2010). Thus, only a selected part of participants is analyzed, i.e., only those who show high compliance. PP therefore reflects an estimate of the 'efficacy' of the intervention (i.e., the working of the intervention under 'ideal circumstances'; Ten Have, Normands, Marcus, Brown & Lacori, 2010). Analyses were performed with SPSS version 23. Reported p-values are two-sided with a significance-level of 0.05.

Missing data

Although we attempted to keep in contact with all randomized participants at post intervention and follow-up - including those who withdrew from the study - not all participants completed all measures. Self-reported baseline data were available for all participants. At T0, six participants (6.3%; EI: $n = 3$, WLC: $n = 3$) did not complete the cognitive performance tests, and eight participants (8.33%; EI: $n = 4$, WLC: $n = 4$) did not take part in the aerobic fitness test. At T1, for the self-reported outcomes, the attrition rate was 9.4% (EI: $n = 7$, WLC: $n = 2$). At this point in time, 19 participants (19.8%; EI, $n = 11$, WLC: $n = 8$) did not complete the cognitive performance tests and 28 (29.3%; EI: $n = 15$, WLC: $n = 13$) did not participate in the aerobic fitness test. At T2, 12 EI participants (24.5% of the 49 EI participants that were randomized) did not provide follow-up data. At T3, 13 EI participants (26.5%) did not provide follow-up data. Participants who did not provide post-intervention data at T1 were younger than those who provided follow-up data ($M = 31.10$ compared to $M = 46.22$, $p < .01$), but did not differ on other demographics and baseline outcomes. Little's overall test of randomness indicated that pre- and post-data were missing completely at random. As a consequence, it was justified to use multiple imputations to estimate missing values (Schafer & Graham, 2002). In case of multiple imputations, missing values are replaced by randomly chosen values that are drawn from an estimate of the distribution of the corresponding variable (Donders, Van der Heijden, Stijnen & Moons, 2006). We used 20 imputations with 100 iterations.

Participants who did not provide follow-up data at T2 and T3 did not significantly differ from those who provided data at these time points, neither on demographics as on baseline outcomes. However, follow-up data (T2 vs T3) were not imputed, since Little's overall test of randomness indicated that the data were not missing completely at random. We based our follow-up analyses on EI participants who completed all measures.

Intervention efficacy

Due to unforeseen (small) baseline imbalances (e.g., in our primary outcome fatigue, see results section), we adapted the analytic strategy from the study protocol (De Vries, Van Hooff, Geurts & Kompier, 2015). Originally, we planned to test the effects of the exercise intervention by using 2x2 repeated measures (M)ANOVAs. However, as literature suggests that univariate analyses of covariance (ANCOVA) better controls for baseline imbalance (Rausch, Maxwell & Kelley, 2003; Vickers, 2001), and generally has greater statistical power to detect intervention effects than other methods such as RM-ANOVA, we preferred to use ANCOVA in the present study. This means that the EI and WLC group were compared on all outcomes at T1, using T0 scores as covariates. Partial eta-squared (η^2) was reported as effect size, and values between .01–.06 were considered as small, .06–.14 as medium, and ≥ .14 as large (Cohen, 1988). For reported Cohen's d, effect sizes of 0.2-0.5 were considered as small, 0.5-0.8 as medium and ≥ 0.8 as large (Cohen, 1988).

Clinical meaningfulness

To assess the clinical meaningfulness of the EI-changes in our primary outcomes (Jacobson & Truax, 1991), we performed Chi-Square Tests to see if the number of participants who scored below cut-off scores of work-related fatigue (UBOS <2.2; FAS <22) after the intervention period (T1) differed between the intervention and the control condition. Need for recovery was not included in this analysis due to the absence of clear cut-off scores for this scale.

Follow-up effects

To investigate whether intervention-effects were maintained at follow-up, for each primary and secondary outcome, a repeated measures ANOVA was performed to see whether the outcome differed between pre (T0), post (T1), 6 weeks after the intervention period (T2), and 12 weeks after the intervention period (T3). If the overall time effect of ANOVA was significant, difference contrasts were computed to exactly determine between what time points the outcome had changed. As follow-up measures were only available for the EI group, WLC participants were not included in these analyses.

Follow-up effects in relation to maintenance of exercise

To investigate whether follow-up effects differed as a function of whether EI group participants engaged in regular exercise during the follow-up period, we performed separate RM-ANOVAs for the first (1-6 weeks after the intervention; T1–T2) and second (6-12 weeks after the intervention; T2-T3) follow-up period. For each outcome, engaging in exercise (yes versus no) was added as between-subjects factor to the model, and time (T1 versus T2 or T2 versus T3) was added as within-subjects factor. Significant time*exercise interaction effects were further examined by paired-sample t-tests.

Results

Sample characteristics

Details of participants' general, work and health characteristics are presented in Table 4.1. We tested whether participants' work characteristics changed throughout the intervention period, since work-related fatigue is closely related to work (Techera, Hallowell, Stambaugh & Littlejohn, 2016). No significant change in work characteristics was observed. Detailed results can be obtained from the first author on request. Employees worked in a variety of occupations, and most were employed in the education or health care sector. The sample consisted primarily of females (80.2%) and most had at least a Bachelor's degree (62.5%). Multivariate analyses and Chi Square tests revealed that participants in the two conditions did not significantly differ on most pre-intervention characteristics, except that the EI group scored lower on job demands (d = 0.49) and more often reported that they had irregular working hours (EI: n = 17 and WLC: n = 9). We checked if these differences affected our study's conclusions, but including job demands and irregular work hours as covariates in the analyses did not change our results.

There were also significant baseline differences between conditions in our outcome measures (see Table 4.2 for means and standard deviations). In general, the EI group was less fatigued than the WLC group, as they scored significantly lower on emotional exhaustion (between group Cohen's d = 0.37), overall fatigue (d = 0.52), and need for recovery (d = 0.53). EI group participants also reported significantly higher general self-efficacy (d = 0.40) and aerobic fitness (d = 0.54) than WLC participants. Given the blinded randomization to the different conditions, these differences are regarded as chance findings.

Table 4.1. *Baseline characteristics of participants in exercise intervention (EI) group and wait list control (WLC) group.*

	EI group (*N*= 49)				WLC group (*N*= 47)			
General	*M*	*SD*	*n*	%	*M*	*SD*	*n*	%
Age	44.2	11.9			46.29	9.30		
Female			39	79.6			38	80.9
Education level[a]								
Low			7	14.3			8	17.0
Moderate			10	20.4			11	23.4
High			32	65.3			28	59.6
Household								
Single			8	16.3			7	14.9
Single, with child(ren)			2	4.1			7	14.9
Cohabiting/married with partner			2	4.1			2	4.3
Cohabiting/married with partner and child(ren) living at home			14	28.6			8	17.0
Cohabiting/Married with partner and child(ren) not living at home			15	30.6			19	40.4
Other			8	16.3			4	8.5
Work								
Employment contract								
Permanent [indefinite time]			36	73.5			33	70.2
Temporary [with prospect on permanent]			4	8.2			5	10.6
Temporary [for fixed term]			9	18.4			6	12.8
Self-employed			0	0			3	6.4
Contractual weekly working hours	29.3	9.5			29.4	10.49		
Weekly work days	4.1	1.0			4.2	1.2		
Weekly working hours overtime (paid and unpaid)	3.5	5.1			4.2	4.9		
Daily commuting hours (h:m)	0:42	0:30			0:56	0:49		
Irregular working hours			15	30.6			9	18.4
Shiftwork								
Evening			12	24.5			9	18.4
Night			6	12.2			1	2.1
Weekend			21	42.9			16	34.0
Job demands[b]	2.4	0.5			2.7	0.7		
Job autonomy[c]	2.9	0.9			3.0	0.8		
Health behaviour								
Weekly alcoholic consumptions	3.8	3.9			2.6	2.5		
Smoking			7	14.3			4	8.5
Physical activity norm[d]	3.3	2.4			2.6	2.2		
Body Mass Index (BMI)	24.3	3.4			24.7	5.3		

[a] low = no education, primary school or secondary school; moderate = intermediate vocational education; high = higher education, such as a university degree

[b] 1 = low, 4 = high, i.e., 'working fast/under high pressure', measured with the Dutch version of the Job Content Questionnaire (Houtman, 1995, Karasek et al., 1998)

[c] 1 = low, 4 = high. i.e., 'control over work situation', measured with the Dutch version of the Job Content Questionnaire (Houtman, 1995, Karasek et al., 1998)

[d] Amount of days at which participants engaged in at least 30 minutes of moderate-intensity physical activity

Table 4.2. *Means and standard deviations for participants in the EI (N = 49) and WLC (N = 47) group of emotional exhaustion, overall fatigue, need for recovery, sleep quality, sleep quantity, general self-efficacy, work self-efficacy and work ability pre (T0) and post intervention (T1), at follow-up 6 weeks (T2) and 12 weeks (T3) after the intervention. (Table continues on next page)*

Outcome (theoretical range)	Group	T0		T1			Intervention effects[b]		T2		T3		Follow-up effects[c]		
		M	*SD*	*M*	*SD*	*d*[a]	*F*	η^2	*M*	*SD*	*M*	*SD*	*F*	Effect	*d*
Emotional Exhaustion (0-6)	EI	3.28	0.87	2.57	1.37	-0.62	2.95	.03	2.17	1.26	2.21	1.14	**16.19****	**T0 vs T1****	**-0.62**
														T0 vs T2**	**-1.03**
														T1 vs T2*	**-0.30**
	WLC	3.62	0.98	3.26	1.41	-0.30								**T0 vs T3****	**-1.06**
														T1 vs T3	-0.29
														T2 vs T3	0.03
Overall Fatigue (10-50)	EI	27.43	4.36	24.62	5.78	-0.55	3.89	.04	22.51	5.28	22.97	5.28	**14.71****	**T0 vs T1****	**-0.55**
	WLC	30.15	6.05	28.63	6.97	-0.23								**T0 vs T2****	**-1.02**
														T1 vs T2**	**-0.38**
														T0 vs T3**	**-0.92**
														T1 vs T3	-0.30
														T2 vs T3	0.09
Need for Recovery (1-4)	EI	2.54	0.61	2.33	0.69	-0.32	2.21	.02	2.21	0.64	2.17	0.62	**5.36***	**T0 vs T1****	**-0.32**
	WLC	2.89	0.71	2.76	0.94	-0.16								**T0 vs T2****	**-0.53**
														T1 vs T2	-0.18
														T0 vs T3**	**-0.60**
														T1 vs T3	-0.24
														T2 vs T3	-0.06
General self-efficacy (1-5)	EI	3.74	0.41	3.78	0.43	0.09	2.11	.02	3.76	0.64	3.66	0.49	0.42	T0 vs T1	0.09
	WLC	3.56	0.51	3.53	0.59	-0.05								T0 vs T2	0.04
														T1 vs T2	-0.04
														T0 vs T3	-0.18
														T1 vs T3	-0.26
														T2 vs T3	-0.18

Table 4.2. *Means and standard deviations for participants in the EI (N = 49) and WLC (N = 47) group of emotional exhaustion, overall fatigue, need for recovery, sleep quality, sleep quantity, general self-efficacy, work self-efficacy and work ability pre (T0) and post intervention (T1), at follow-up 6 weeks (T2) and 12 weeks (T3) after the intervention. (Continued)*

Outcome (theoretical range)	Group	T0		T1			Intervention effects[b]		T2		T3		Follow-up effects[c]		
		M	*SD*	*M*	*SD*	*d*[a]	*F*	η^2	*M*	*SD*	*M*	*SD*	*F*	Effect	*d*
Work self-efficacy (0-6)	EI	4.07	1.01	4.24	1.03	0.17	0.49	.01	3.91	0.96	3.97	1.04	1.37	T0 vs T1	0.17
	WLC	3.91	0.93	4.06	1.14	0.14								T0 vs T2	0.16
														T1 vs T2	-0.33
														T0 vs T3	-0.10
														T1 vs T3	-0.26
														T2 vs T3	0.06
Sleep Quality (0-6)	EI	3.62	1.54	3.06	1.74	-0.35	**5.33***	**.06**	2.78	1.83	2.89	1.82	**3.96***	**T0 vs T1****	**-0.35**
	WLC	3.61	1.22	3.72	1.44	0.08								**T0 vs T2****	**-0.50**
														T1 vs T2	-0.16
														T0 vs T3**	**-0.43**
														T1 vs T3	-0.10
														T2 vs T3	0.06
Sleep Quantity	EI	7.09	0.96	7.05	0.94	-0.04	0.06	0	7.18	0.95	7.11	0.88	0.10	T0 vs T1	-0.04
	WLC	7.08	0.91	7.06	0.93	-0.02								T0 vs T2	0.09
														T1 vs T2	0.14
														T0 vs T3	0.02
														T1 vs T3	0.07
														T2 vs T3	-0.08
Work ability (1-10)	EI	7.73	1.32	7.96	1.58	0.16	**4.26***	**.05**	8.03	1.40	7.63	1.78	1.16	T0 vs T1	0.16
	WLC	7.08	2.20	6.90	2.14	-0.08								T0 vs T2	0.22
														T1 vs T2	0.05
														T0 vs T3	-0.06
														T1 vs T3	-0.20
														T2 vs T3	-0.25

[a] Within-group Cohen's *d*
[b] Pre- and post-comparisons: ANCOVA with the post-intervention score (T1) as dependent variable and the baseline score (T0) as covariate.
[c] RM-ANOVAs for the EI group only.
* $p < .05$, ** $p < .01$

4

Compliance

EI group participants completed on average 11.88 (*SD* = 5.86) of the in total 18 exercise sessions. This number includes the four participants who did not receive the exercise intervention and the 14 participants who discontinued the intervention. Participants who discontinued the intervention completed on average 5.00 (*SD* = 4.12) exercise sessions. Reasons for dropout can be found in Figure 4.1. The 31 participants who completed the intervention did on average 15.12 (*SD* = 3.46) exercise sessions. Participants who did not receive or discontinued the intervention were similar to completers as to demographics and primary and secondary outcomes at baseline.

In the WLC group, between T0 and T1, ten participants appeared to exercise ≥ one hour a week (*M* = 95.92 minutes, *SD* = 38.53). Exercising less than one hour a week was set as an inclusion criterion to be eligible to be included in this study. Thus, ten participants increased their exercise level during the wait period. They did not differ from those who did not increase their exercise level as regards demographics and primary and secondary baseline outcomes.

Intention to treat: pre- and post-comparisons

Work-related fatigue

Means and standard deviations of the three indicators of work-related fatigue pre- and post-intervention are presented in Table 4.2. The three indicators were significantly inter-related (at T0: emotional exhaustion and overall fatigue $r = .56$; emotional exhaustion and need for recovery $r = .59$; overall fatigue and need for recovery $r = .50$). The EI group did not report significantly lower emotional exhaustion, overall fatigue and need for recovery at post-intervention than the WLC group.

Clinical meaningfulness

Table 4.3 presents the number of participants who improved, recovered, unimproved and deteriorated (Jacobson & Truax, 1991) after the intervention period (T1) with respect to emotional exhaustion and overall fatigue. Chi Square Tests revealed that the number of participants who scored below cut-off scores of fatigue after the intervention period (i.e., 'recovered') was higher among EI participants for both emotional exhaustion ($\chi^2 = 5.19$, $p = .03$) and overall fatigue ($\chi^2 = 4.78$, $p = .04$) compared to WLC participants.

General and work-related self-efficacy

As can be seen in Table 4.2, the EI group did not display higher general and work-related self-efficacy levels at post-intervention when compared to the WLC group.

Table 4.3. *Clinical meaningfulness: number and percentages of participants who improved, recovered, unimproved or deteriorated with respect to emotional exhaustion and overall fatigue from T0 to T1.*

		Improved		Recovered[a]		Unimproved or deteriorated	
		N	%	N	%	N	%
EI	Emotional exhaustion	36	73.5	22	44.9	13	26.5
	Overall fatigue	32	73.8	16	47.6	17	26.2
WLC	Emotional exhaustion	28	59.6	11	23.4	19	40.4
	Overall fatigue	28	59.6	7	14.9	19	40.4

[a] Emotional exhaustion: ≤2.2 on Utrecht Burnout Scale; Overall fatigue: ≤22 on Fatigue Assessment Scale.

Sleep quality and quantity

The EI group reported significantly better sleep quality at post-intervention than the WLC group (moderate effect, see Table 4.2). No differences at post-intervention between groups were found as regards sleep quantity.

Work ability

At post-intervention, the EI group reported significantly higher levels of work ability when compared to the WLC group (small effect, see Table 4.2).

Cognitive functioning

Table 4.4 presents the means and standard deviations of self-reported and objectively measured cognitive functioning. The EI group reported better self-reported cognitive functioning at T1 compared to the WLC group (moderate effect). No differences at T1 between groups were found for the cognitive performance tasks (measuring 'updating', 'switching', and 'inhibition') nor for the subjective costs associated with doing the cognitive performance tasks.

Aerobic fitness

Table 4.5 displays the means and standard deviations of VO_{2max} obtained from the UKK walk test and the subjective costs associated with performing this test. At T1, no differences between the EI and WLC group were found as regards aerobic fitness and related subjective costs.

Table 4.4. *Means and standard deviations of indicators of cognitive functioning pre (T0) and post (T1) intervention.*

Outcome (theoretical range) [cognitive task]		T0		T1			Intervention effects[d]	
	Group	*M*	*SD*	*M*	*SD*	*d*[a]	*F*	η^2
Self-reported cognitive functioning (0-100)	EI	40.68	13.12	37.33	11.21	-0.28	**5.97***	**.06**
	WLC	43.72	11.92	43.73	12.93	<.01		
Updating [N-back][b]	EI	58.82	19.14	67.42	21.20	0.43	0.43	<.01
	WLC	57.63	23.57	65.27	20.03	0.32		
Inhibition [SART][b]	EI	31.39	8.31	33.56	10.87	0.22	1.03	.01
	WLC	33.60	8.82	33.09	10.29	-0.05		
Switching [Matching Task][c]	EI	144.83	165.89	97.74	154.08	-0.29	0.54	.01
	WLC	90.76	139.66	87.99	153.65	-0.02		
Subjective costs (1-10)								
Fatigue (before)	EI	5.90	1.75	5.25	2.62	-0.29	1.06	.01
	WLC	5.44	2.18	5.62	2.28	0.08		
Fatigue (after)	EI	6.67	1.86	6.06	2.52	-0.13	0.34	<.01
	WLC	7.70	1.12	6.21	2.37	-0.80		
ΔFatigue[e]	EI	0.76	1.83	0.82	2.05	0.03	0.57	.01
	WLC	1.07	1.85	0.59	2.21	-0.24		
Motivation	EI	8.70	1.39	8.76	1.19	0.05	2.28	.02
	WLC	9.09	1.02	8.54	1.27	-0.48		
Demands	EI	7.44	1.26	6.73	1.77	-0.46	3.48	.04
	WLC	7.70	1.12	7.44	1.74	-0.18		
Effort	EI	8.78	1.10	8.87	1.19	0.08	1.06	.01
	WLC	8.82	1.08	8.69	1.25	-0.11		

[a] Within-group Cohen's d

[b] Number of correct responses

[c] Switch cost in milliseconds

[d] Pre- and post-comparisons: ANCOVA with the post-intervention score (T1) as dependent variable and the baseline score (T0) as covariate.

[e] Difference in fatigue before and after the cognitive test battery

* $p < .05$, ** $p < .01$

Follow-up effects

Most of the participants who filled out follow-up questionnaires, had completed the intervention (*n* = 30 at T2 and at T3). Seven (T2) and respectively six (T3) had discontinued the intervention. Results of the repeated measures ANOVA's that were conducted to examine follow-up effects are displayed in Table 4.2. This table also presents means and standard deviations of outcome measures 6 weeks (T2) and 12 weeks (T3) after the end of the intervention. EI participants showed a decrease in emotional exhaustion, overall fatigue, need for recovery and sleep quality from baseline (T0) to post intervention (T1) and to follow-up (both at T2 and T3). From post-intervention (T1) to 6 weeks after the intervention (T2), we found small further improvements in emotional exhaustion and overall fatigue. For none of the primary or secondary outcomes we found improvements from 6 weeks after the intervention (T2) to 12 weeks after the intervention (T3).

Table 4.5. *Means and standard deviations of aerobic fitness pre (T0) and post (T1) intervention.*

Outcome (theoretical range)		T0		T1			Intervention effects[c]	
	Group	*M*	*SD*	*M*	*SD*	*d*[b]	*F*	η^2
Aerobic fitness (VO_2max)	EI	30.89	6.02	32.18	7.10	0.20	1.32	.01
	WLC	27.65	6.01	29.72	7.07	0.32		
Subjective costs (1-10)								
Fatigue (before)	EI	5.65	1.90	5.00	2.62	-0.28	2.15	.02
	WLC	6.21	2.11	5.83	2.31	-0.17		
Fatigue (after)	EI	4.95	1.85	4.23	3.04	-0.29	2.73	.03
	WLC	5.28	1.86	5.11	2.50	-0.08		
ΔFatigue[a]	EI	-0.70	2.35	-1.02	3.06	0.12	1.54	.02
	WLC	-0.94	2.02	-0.50	2.90	0.18		
Motivation	EI	9.00	0.96	8.92	1.05	-0.08	1.21	.01
	WLC	8.61	1.26	8.57	1.20	-0.03		
Demands	EI	4.88	2.29	4.00	2.59	-0.36	4.51	.05
	WLC	4.73	2.25	4.99	2.53	0.11		
Short of breath	EI	3.74	2.23	3.31	2.37	-0.19	1.50	.02
	WLC	4.12	2.24	3.89	2.56	-0.10		
Effort	EI	9.16	0.79	9.03	1.23	-0.13	0.92	.01
	WLC	8.76	1.01	8.93	1.12	0.16		

[a] Within-group Cohen's d
[b] Pre- and post-comparisons: ANCOVA with the post-intervention score (T1) as dependent variable and the baseline score (T0) as covariate.
[c] Difference in fatigue before and after the aerobic fitness test
* p < .05, ** p < .01

Follow-up effects in relation to maintenance of exercise

At T2, 23 participants indicated that they had engaged in regular exercise since they finished the intervention (*M* = 133.48, *SD* = 104.69 minutes a week). No differences in the development of outcomes from T1 and T2 were found between those who continued exercising and those who did not continue exercising in this period (i.e., no significant time*exercise interactions; *F*'s ranging from 0.07 – 4.06, all *p*'s >.05).

At T3, 21 participants reported that they had engaged in regular exercise since six weeks after the end of the intervention (M =178.00, SD = 165.13 a week). A significant time*exercise interaction for need for recovery was found ($F_{1,33}$ = 10.27, $p < .01$, $\eta^2 = .24$). T-tests revealed that participants who continued exercising in this period showed a (marginally significant) decrease in need for recovery from T2 to T3 (d = -0.39, t = 2.02, p = 0.06), while those who stopped exercising showed an increase in need for recovery (d = 0.54, t = -2.75, p = .02). Other outcomes were not related to the amount of exercise participants engaged in the period between T2 and T3 (i.e., no significant time*exercise interactions); *F*'s ranging from 0.08 – 3.11, all *p*'s > .05)

Per protocol analysis

In PP analyses, we only analyzed participants who complied to the protocol. We considered EI participants to have complied with the protocol if they completed the intervention and WLC participants if they exercised less than one hour during the wait period. Results of PP analyses are only presented when different from ITT analyses (see Appendix A for all results of PP analyses).

The EI group (n = 31) and WLC group (n = 35) were compared on T1 outcomes by means of ANCOVAs with respective T0 scores as covariates. The ANCOVA analysis revealed that the EI group scored significantly lower at T1 on emotional exhaustion (M = 2.44, SD = 1.25; $F_{1,61}$ = 4.42, p = 0.04, $\eta^2 = .06$) and on overall fatigue (M = 24.03, SD = 5.63; $F_{1,63}$ = 4.42, p = 0.04, $\eta^2 = .06$) when compared to the WLC group (M =3.24, SD = 1.31; M = 29.14, SD = 7.10 respectively).

Similar significant results, but (slightly) higher effect sizes were observed for PP analyses when compared to ITT analyses as regards sleep quality ($F_{1,63}$ = 5.54, p = 0.02, $\eta^2 = .08$), work ability ($F_{1,63}$ = 4.58, p = 0.04, $\eta^2 = .07$) and self-reported cognitive functioning ($F_{1,63}$ = 10.50, p < 0.01, $\eta^2 = .14$). Furthermore, in contrast to ITT analyses, PP analyses showed that part of subjective costs of both cognitive performance tests as well as aerobic fitness test were lower for EI participants as compared to WLC participants. That is, at T1 the EI group was less fatigued before doing the cognitive performance tests (M = 4.75, SD = 1.92; $F_{1,57}$ = 7.05, p = 0.01, $\eta^2 = .11$) when compared to the WLC group (M = 6.00, SD = 1.84). Additionally, the EI group participants reported lower fatigue before (M = 4.79, SD = 1.95; $F_{1,54}$ = 7.56, p = 0.01, $\eta^2 = .12$) and after (M = 3.59, SD = 1.92; $F_{1,54}$ = 6.45, p = 0.01, $\eta^2 = .11$) the aerobic fitness test, and considered the test as less demanding (M = 4.00, SD = 1.79; $F_{1,54}$ = 5.34, p = 0.03, $\eta^2 = .09$) compared to WLC participants (M = 6.21, SD = 1.91; M = 5.32, SD = 1.91; M = 5.25, SD = 2.08 respectively).

Discussion

In order to better understand the causal association between exercise and work-related fatigue, the present study evaluated the efficacy of an exercise intervention on i) work-related fatigue (primary outcome) and on ii) self-efficacy, sleep, work ability, cognitive functioning and aerobic fitness (secondary outcomes).

As to our primary outcome, ITT analyses revealed no effects of EI on the three indicators of work-related fatigue as compared to WLC. We did find that the number of EI participants who 'recovered' with respect to emotional exhaustion and overall fatigue was higher when compared to WLC participants, but this result should be interpreted with caution, since EI participants were less fatigued at baseline and, as a consequence, less improvement was needed in order to be 'recovered'. A closer examination of the EI and WLC groups reveals that some participants in the EI group did not start exercising or gave up exercising before T1, whereas some of the WLC group members did not wait but increased their exercise level between T0 and T1. The latter behavior may reflect their motivation to exercise, i.e., reflect the reason why they were willing to take part in this study. PP analyses between 'pure' groups of 'completers' and 'true controls' showed that EI participants displayed lower emotional exhaustion and overall fatigue compared to WLC at post-intervention. Together, this means that a) exercise is effective to reduce emotional exhaustion and overall fatigue, and b) that sufficient exposure to exercise ('compliance') is needed in order to observe beneficial effects. These results are in accordance with previous intervention studies that concentrated on participants who completed the exercise intervention (Bretland & Thorsteinsson, 2014; Freitas, Carneseca, Paiva & Paiva, 2014; Gerber et al., 2013; Tsai et al., 2013; Van Rhenen, Blonk, Van der Klink, Van Dijk & Schaufeli, 2005). Further small improvements in emotional exhaustion and overall fatigue were found 6 weeks after the end of the intervention, and these were maintained at 12 weeks. Similar to ITT analysis, PP analysis revealed no significant post-intervention between-group difference in need for recovery, but follow-up results indicated that EI participants showed a moderate improvement in need for recovery from baseline to 6 weeks and 12 weeks after the intervention, and for those who engaged in regular exercise a further improvement between 6 and 12 weeks after the intervention.

Significant effects were also found for a number of secondary outcomes. Similar to previous intervention studies (Kredlow, Capozzoli, Hearon, Calkins & Otto, 2015), a moderate effect of EI on sleep quality was found in both ITT and PP analyses. Effects on sleep quality were maintained at follow-up. The small improvement in work ability in the EI group compared to the WLC group both in ITT and PP analyses, is in accordance with previous suggestions that exercise increases employees' physical and psychological capabilities to effectively cope with work demands (Arvidson, Börjesson, Ahlborg, Lindegård & Jonsdottir, 2013; Van den Berg, Elders, De Zwart & Burdorf, 2009). EI participants also reported better cognitive functioning compared to WLC participants at T1, indicating less problems with attentiveness and memory in everyday life (Bridger, Johnsen & Brasher, 2013). PP analyses revealed larger effect sizes in sleep quality, work ability and self-reported cognitive functioning than ITT analyses. This implies that the 'received dose' of the intervention also impacted intervention's efficacy with respect to these outcomes.

Contrary to expectations, no improvement was found in some other secondary outcomes. We found no effects of EI on general and work-related self-efficacy. It is possible that exercise is particularly related to mastery feelings relating to the exercise domain (i.e., 'exercise self-efficacy'; McAuley & Blissmer, 2000) and that these feelings are not (yet) transferred to other life domains. Also, no difference between groups with regard to sleep quantity was found. It is possible that a stronger exercise 'dose' would have resulted in improvements of sleep quantity (Kredlow, Capozzoli, Hearon, Calkins & Otto, 2015). We also did not find a between-group difference at post-intervention in objective cognitive performance and aerobic fitness (Vo_{2max}). However, PP analysis revealed that EI participants considered the aerobic fitness test as less demanding than WLC participants at post-intervention, which might suggest positive changes in capacity. It is plausible that low intensity exercise needs to be maintained longer than six weeks to observe improvements in VO_{2max} (Gormley et al., 2008).

Limitations

Six critical issues of this study deserve further attention. First, despite a 'state of the art' concealed allocation to groups, baseline imbalances with respect to work characteristics and outcome measures occurred. Baseline imbalances may result in chance bias. This means that differences in group outcomes could accidentally be due to participants characteristics, not the intervention (Roberts & Torgerson, 1999). Baseline differences in indicators of fatigue were, however, not large but small to moderate (Cohen's d's between 0.37-0.54), and differences in job demands and irregular working hours were not substantially related to our primary outcomes (*r* ranging from -.02 to .25; Roberts & Torgerson, 1999). Furthermore, by analyzing our data by means of ANCOVA, we used the preferred method to control for baseline imbalances (Rausch, Maxwell & Kelley, 2003; Vickers, 2001). It is therefore not plausible that this issue seriously impacted our findings.

The second issue is the non-blinded waitlist design. This was considered to be the best option, given our aim to compare exercise to the 'natural course' of work-related fatigue in absence of a gold standard intervention to reduce it. WLC participants may not truly be 'untreated', since they are contacted, consented, randomized and measured (McCambridge, Kypri & Elbourne, 2014). Such research participation effects may possibly contribute to a change in behavior and outcomes between T0 and T1, as evidenced by the increased exercise activity among WLC participants between T0 and T1. The waitlist design also implied that WLC participants were offered the intervention following T1, and hence no comparison between groups could be made at follow-up. This limits strong conclusions about follow-up effects. Furthermore, as result of this design, we cannot assess the extent to which non-specific intervention factors (i.e., factors other than exercise itself) contribute to the reported beneficial effects. Peer support in the group exercise sessions might have acted as a non-specific intervention factor. Future studies may compare individual and group exercise interventions to shed more light on this matter. They may also investigate the amount of social (peer) interaction before, during and directly after each exercise session between participants. Attention of the trainers/researchers might be regarded as another potential non-specific factor. WLC participants received less attention than EI participants. From our data it was not possible to assess the potential contribution of this ingredient to the reported beneficial effects. Future research may design the control group in a way to control for the factor attention (see Lindheimer, O'Connor & Dishman, 2015; Mohr et al., 2009).

Third, the feasibility of our intervention requires attention. Thirty-four (18.9%) out of 180 eligible employees were not able or willing to participate in the exercise intervention (see Figure 4.1). Another fifty employees (27.8%) were willing to engage in the intervention, but declined to participate because of lack of time to attend the two group-based supervised sessions, for instance due to family obligations. This is unfortunate, as it indicates that fatigued employees may well be motivated for participation in an exercise intervention, but at the same time practical considerations limit them to do so. Additionally, 14 (28.6%) of EI participants dropped out during the intervention, often because of injuries (n = 7, see Figure 4.1). We tried to minimize injury risk by applying a graded running protocol, in which low-intensity running was built up slowly and walking periods gradually decreased. As among intervention-completers compliance was high (i.e., 83.9%), which suggests that the intervention was appreciated, future studies might try to further tailor the intervention to participants' practical possibilities. Future studies might also consider other exercise types. For example, in case of a running injury alternative, less demanding exercise activities (e.g. cycling) could be 'prescribed'.

Fourth, given that we only included employees who at the study start exercised < 1 hour a week, our sample consisted of (relatively) inactive employees. This implies that our study findings cannot be 'simply' generalized to other fatigued employees who already exercise on a more regular basis. Further work is required to establish how exercise can benefit this population, for instance by further investigating the optimal exercise dose to reduce work-related fatigue.

Fifth, this study might have benefitted from other approaches to measure exercise and sleep, such as diaries or ambulatory devices (see also Prince et al., 2008; Van de Water, Holmes & Hurley, 2011). Future studies may include such measures to assess exercise and sleep more thoroughly.

Sixth, the interpretation of our study's results might have been improved by conducting a process evaluation of the intervention (Biron & Karanika-Muray, 2014). We mainly concentrated on effect-evaluation of the intervention, i.e., a comparison of pre- and post-intervention outcomes. However, also process factors may explain intervention results (Biron & Karanika-Muray, 2014; Kompier & Aust, 2016), as is indeed acknowledged in the current intervention's study protocol (De Vries, Van Hooff, Geurts & Kompier, 2015). For instance, processes such as the quality of the intervention provider and participants' mental models, may have affected the results of the intervention. Future exercise trials may include relevant process factors in their evaluation of the intervention in order to better understand its outcomes. Practical frameworks may help to guide these future process evaluations (e.g., Nielsen & Randall, 2013; Steckler & Linnan, 2002).

Theoretical and practical contributions

This study contributes to the scientific evidence on the effect of exercise on work-related fatigue in a theoretical and practical sense. As regards the former, based on psychological (e.g., detachment; Feuerhahn, Sonnentag & Woll, 2014; Ten Brummelhuis & Bakker, 2012; Sonnentag, 2012) and physiological (e.g., faster stress recovery; Klaperski, Von Dawans, Heinrichs & Fuchs, 2014) mechanisms, we expected that exercise would reduce work-related fatigue. By adopting a randomized controlled trial design, causal inferences could be reached at. We found that exercise indeed 'works' to reduce work-related fatigue, and to enhance broader indicators of employee well-being (sleep quality, work ability and cognitive functioning). Given that mechanisms underlying the relationship between exercise and work-related fatigue are hardly empirically studied, future research into these mechanisms would help to enhance further theory development. Because sufficient compliance played a role in whether beneficial effects of exercise were found, this study provides an example for future effectiveness trials in which the (implementation of) the exercise intervention can be further investigated (Glasgow, Lichtenstein & Marcus, 2003).

As regards practical contributions, this study showed that exercise can serve as a relatively simple and inexpensive secondary prevention strategy to improve well-being in employees with high levels of work-related fatigue, especially if compliance is high. As such, it not only provides a practical tool for employees wanting to reduce their levels of fatigue, but may also help employers, health practitioners and policy makers when aiming to implement evidence-based guidelines to reduce fatigue among employees.

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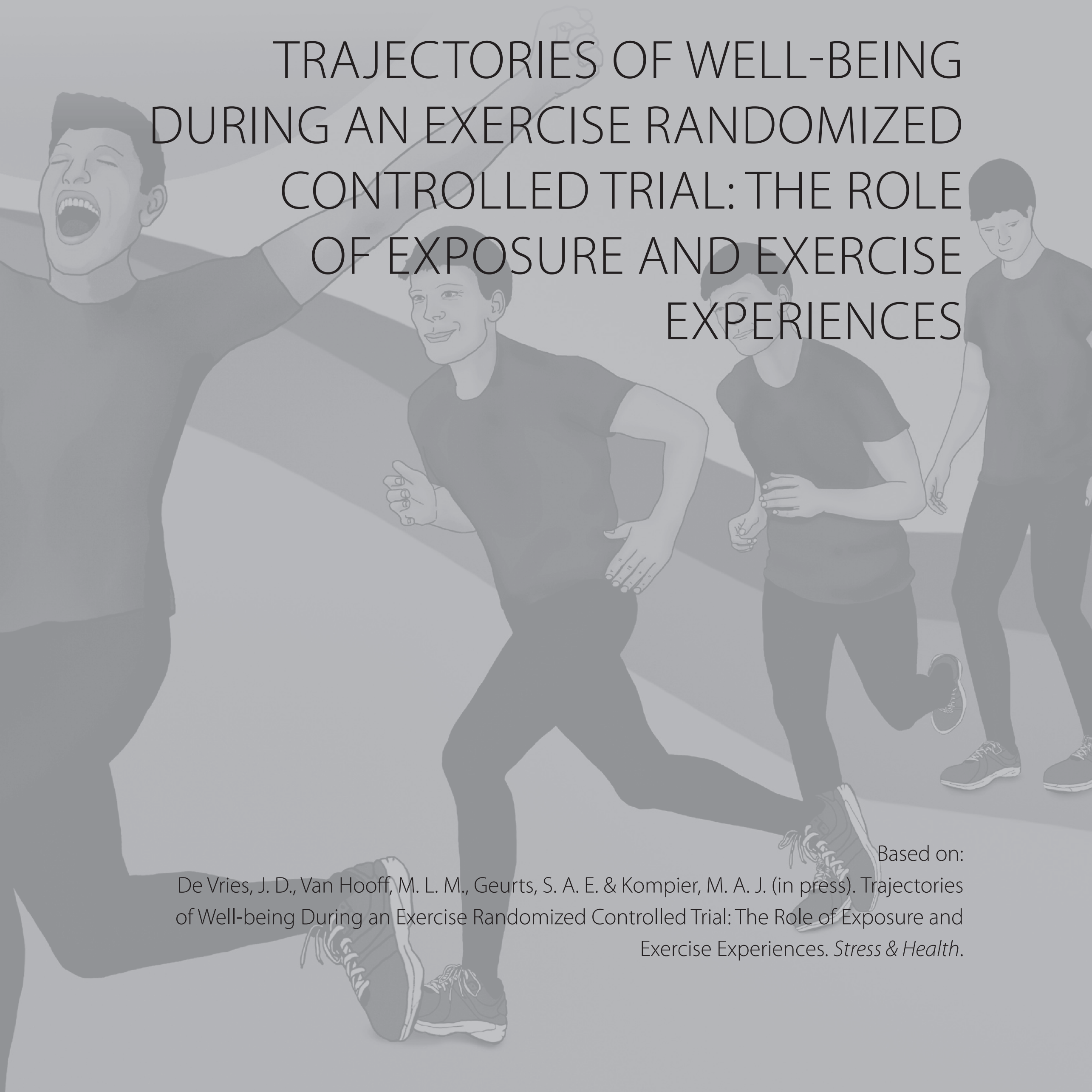
CHAPTER 5

TRAJECTORIES OF WELL-BEING DURING AN EXERCISE RANDOMIZED CONTROLLED TRIAL: THE ROLE OF EXPOSURE AND EXERCISE EXPERIENCES



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Abstract

Purpose

We examined how process factors were related to the development of various indicators of well-being during the course of an exercise randomized controlled trial aimed at reducing fatigue among university students. We investigated i) whether actual exposure to the exercise sessions was related to differences in students' trajectories of well-being, ii) the minimally required exposure to exercise needed before well-being started to differ between the intervention and control condition, and iii) whether exercise experiences (enjoyment and detachment) were related to differences in well-being trajectories.

Methods

University students with high levels of fatigue were randomly allocated to a six-week exercise intervention ($n = 50$) or wait list ($n = 49$). All participants were measured before, five times during, and at the end of the intervention period.

Results

Multilevel analyses showed that exercisers with high exposure showed an increase in self-efficacy whereas those with low exposure did not. Effects of exercise on well-being became visible after 2 to 4 weeks during the intervention period, and (partly) depended on the extent of psychological detachment.

Conclusion

We recommend that both outcomes and process factors throughout the intervention period should be measured in order to better understand 'when' and 'under what conditions' an exercise intervention works.

Introduction

Many university students suffer from study stress, for example due to increased performance demands (Schaufeli, Martínez, Marques Pinto, Salanova & Bakker, 2002; Vossensteyn, Cremonini, Epping, Laudel & Leisyte, 2013). Prolonged stress may hamper students' ability to successfully fulfill study demands and result in decreased well-being, as indicated by higher levels of fatigue or lower levels of satisfaction (Cotton, Dollard & De Jonge, 2002; Schaufeli, Martínez, Marques Pinto, Salanova & Bakker, 2002). A large body of research indicates that exercise is beneficial for a range of indicators of well-being. Exercise ameliorates depression (Cooney et al., 2013) and anxiety (Wipfli, Rethorst & Landers, 2008), and positively affects fatigue, quality of life and self-esteem (e.g., Ekeland, Heian, Hagen, Abbott & Nordheim, 2004; Gill et al., 2013; Larun, Brurberg, Odegaard-Jensen & Price, 2016). Several plausible hypotheses underlying this relationship have been proposed. For instance, exercise may help students to distract themselves from negative thoughts, or to obtain mastery experiences resulting in increased self-efficacy (Craft & Perna, 2004). Exercise may also induce changes in several neurotransmitters and neuromodulators resulting in increased well-being (see Dishman et al., 2006 for an overview). Another hypothesis is that fitter individuals show more rapid cardiovascular recovery from stressors, and are more resilient to stress (Gerber & Pühse, 2009).

The few available intervention studies indeed show that exercise is beneficial for student well-being (e.g., Puetz, Flowers & O'Connor, 2008; Nabkasorn et al., 2005; Stein & Motta, 1992). In these intervention studies emphasis is placed on outcome evaluation: a comparison of participants' well-being levels before and after the intervention period. Consequently, there is still little insight in the processes that take place during the intervention period and that ensure successful intervention outcomes or that may be held responsible for intervention failure. Process evaluation is needed to shed light on these issues (Durlak, 2015; Hulscher, Laurant & Grol, 2003; Moore et al., 2015; Murta, Sanderson & Oldenburg, 2005; Steckler & Linnan, 2002). While effect evaluation answers the question 'does the intervention work?', process evaluation seeks answers to questions as 'what are factors that hindered or stimulated change?' and 'under what circumstances does an intervention work?' (Nielsen & Randall, 2013). It aids in explaining whether certain results were due to the intervention itself (i.e., a sound theory behind the intervention) or process factors (i.e., perceptions and actions in implementing the intervention; Abildgaard, Saksvik & Nielsen, 2016; Kristensen, 2005). It carefully maps the implementation (i.e., the way a program is put into practice), the mechanisms of impact (i.e., why does the delivered intervention work) and the setting of the intervention (i.e., general intervention and implementation context) and as such helps in interpreting intervention outcomes (Moore et al., 2015; Steckler & Linnan, 2002). This is important since "it is not evidence-based programs that are effective, but it is well-implemented evidenced-based programs that are effective" (Durlak, 2015). Process evaluation is valuable for researchers and practice, since it helps to refine theories, design future effective exercise interventions and to successfully implement exercise interventions (Durlak, 2015; Hulscher, Laurant & Grol, 2003; Murta, Sanderson & Oldenburg, 2005; Steckler & Linnan, 2002).

Process evaluation is complex, since many process factors may influence intervention outcomes (Durlak, 2015). Several practical and conceptual frameworks have been proposed aimed at guiding process evaluation (e.g., Carroll et al., 2007; Glasgow, Vogt & Boles, 1999; Nielsen & Randall, 2013; Moore et al., 2015; Saunders, Evans & Joshi, 2005; Steckler & Linnan, 2002). However, so far, a leading overlapping framework is lacking (Kompier & Aust, 2016). What the various existing frameworks share is a focus on "fidelity" (whether the intervention was delivered as intended) and "dose" (the quantity of intervention implemented; see Moore et al., 2015). Other key elements are "context" (aspects of the environment of the intervention), "reach" (the proportion of the target population that participates in the intervention), "implementation" (the extent to which a program is delivered in practice as intended) and "participant's attitudes toward the intervention" (how participants react to the intervention; Glasgow, Vogt & Boles, 1999; Saunders, Evans & Joshi, 2005; Steckler & Linnan, 2002).

Despite the fact that the importance of process evaluations has been emphasized before (Carroll et al., 2007; Glasgow, Vogt & Boles, 1999; Nielsen & Randall, 2013; Moore et al., 2015; Saunders, Evans & Joshi, 2005; Steckler & Linnan, 2002), to the best of our knowledge, process evaluations of exercise interventions aimed at increasing (student) well-being have as yet received no attention. Hence, what happens during the intervention period of such interventions has remained largely a "black box". In the present study, we therefore aimed to open the "black box" of the intervention period during an exercise randomized controlled trial. To this end, non-regularly exercising students with serious fatigue symptoms were measured before, five times during, and immediately after either a six-week period of regular exercise (i.e., exercise condition) or a wait period (i.e., control condition) on six indicators of well-being and process factors. Process factors included exposure (i.e., "dose"; Moore et al., 2015) and exercise experiences (i.e., "participant's attitudes toward the intervention"; Glasgow, Vogt & Boles, 1999, Saunders, Evans & Joshi, 2005). We focused on weekly measurements of well-being for two reasons. First, this enabled us to portray the development of well-being throughout the intervention period, and to examine at which point in time intervention effects become visible. Second, it has been suggested that changes in outcomes can happen continuously during the intervention as a result of process factors (see Fridrich, Jenny & Bauer, 2015). Therefore, we linked exposure and exercise experiences to well-being trajectories, i.e., we investigated whether these process factors were linked to beneficial changes in well-being indicators during the course of the intervention. Specifically, we investigated: i) whether actual exposure to the exercise sessions was related to differences in students' trajectories of well-being, ii) the minimally required exposure to exercise needed before well-being started to differ between the intervention condition and control condition, and iii) whether experiences (enjoyment and detachment) of those exposed to exercise were related to differences in well-being trajectories.

Exposure to exercise

Exposure to the intervention refers to the amount of an intervention received by participants. It is an important prerequisite for the success of an intervention (Steckler & Linnan, 2002; Saunders, Evans & Joshi, 2005). Studying exposure helps to distinguish between interventions that are not correctly designed (failure of the theory behind the intervention: "it does not help that the patient takes the pill if it has no effect"; Kristensen, 2005) and those that are not correctly delivered (implementation failure: "it does not help that the pill has effect if the patient does not take it"; Kristensen 2005). Thus, the degree to which members of the intervention group actually "took the pills" they were supposed to take (i.e., were exposed to exercise sessions) is essential for the interpretation of intervention outcomes (Kristensen, 2005). It is therefore regarded a key element in all theoretical frameworks aimed at guiding process evaluation (e.g., Glasgow, Vogt & Boles, 1999; Nielsen & Randall, 2013; Moore et al., 2015; Saunders, Evans & Joshi, 2005; Steckler & Linnan, 2002). In case of fatigue, paying attention to exposure to exercise seems especially important, since it has been suggested that engaging in regular exercise is particularly difficult for fatigued individuals (De Vries, Claessens, Van Hooff, Geurts & Kompier, 2015). In the current study, we therefore investigated how many exercise sessions were attended by participants in the exercise condition and whether variations in exposure affected participants' well-being trajectories during the course of the intervention. We expected:

Hypothesis 1: Participants with higher exposure to exercise show a larger improvement in weekly well-being compared to participants with lower exposure

Minimally required exposure

Whereas studying exposure is needed to identify possible variation in intervention outcomes, the question remains how much exposure is necessary in order to observe actual intervention effects, i.e., the minimal intervention duration needed to achieve statistical significant differences in outcome measures between intervention and the control group. Increasing our knowledge about the minimally required exposure may provide guidance for the design of future exercise interventions (Glasgow et al., 2014). In traditional pre-post comparisons we are informed about a (potential) change between the start and the end of the intervention, but detailed in-between-measurements are needed to find out at what point of time changes between the intervention and control condition become visible. Although there are substantial variations in the duration of exercise interventions that have so far been conducted, the minimally required length of an exercise intervention to produce significant changes between exercisers and non-exercisers is not known. Given this blind spot in the literature, we aimed to answer the following research question: What is the minimal exposure to exercise required in order to start seeing changes in student well-being?

Experiences of exercise

Exposure is necessary, but not sufficient for successful intervention effects (Hulscher, Laurent & Grol, 2003; Nielsen & Randall, 2013). Participants are not passively exposed to the intervention, but actively engage in it. This means that participants may also differ in how they experience the same intervention content (Hulscher, Laurent & Grol, 2003; Murta et al., 2005; Nielsen & Randall, 2013). Several conceptual frameworks have therefore emphasized the importance of examining participants' experiences of an intervention (also referred to as participants' mental models or appraisal) in order to understand if and how these experiences may have impacted intervention effects (see Carroll et al., 2007; Fridrich, Jenny & Bauer, 2015; Hulscher, Laurent & Grol, 2003; Nielsen & Randall, 2013). In the current study, we focus on two experiences that have been identified as important in determining the effect of (leisure) activities (such as exercise) on well-being outcomes such as fatigue, namely enjoyment (Oerlemans, Bakker, & Demerouti, 2014; Van Hooff, Geurts, Beckers, & Kopier, 2011) and psychological detachment (i.e., 'mentally disengaging from study'; Sonnentag & Fritz, 2015)

Enjoyment is a crucial feature of leisure activities and reflects positive feelings like fun and pleasure (Kimiecik & Harris, 1996). Exercise enjoyment reflects how one feels about exercise, rather than how one feels in general (Raedeke, 2007). The majority of previous studies paying attention to exercise enjoyment showed its importance for (sustained) motivation for exercise (e.g., Hagberg, Lindahl, Nyberg, & Hellénius, 2009). However, enjoyment during exercise may also affect the extent to which it causes (long-term) beneficial effects on well-being (Fredrickson, 2001; Raedeke, 2007; Wankel, 1993), since it may build stress resilience and trigger upward spirals toward enhanced well-being via people's broadened cognitive and behavioral repertoire (see Broaden and Build theory, Frederickson, 2001). Enjoyment may also activate certain brain networks involved in the regulation of cognition and emotion, and as such increase well-being (Esch & Stephano, 2004). We expected:

Hypothesis 2: Participants who experience higher enjoyment during the exercise sessions show a larger improvement in their weekly trajectories of well-being than participants who experience less enjoyment during these sessions

Psychological detachment during exercise is another experience that may contribute to well-being. Until now, psychological detachment is mainly studied among employees. It refers to a subjective experience in which someone disengages oneself psychologically from work when being away from it (Sonnentag & Fritz, 2015). In case of university students, it comprises not thinking about or bothering with study demands during leisure time (Ragsdale, Beehr, Grebner & Han, 2011). The experience of psychological detachment during exercise may stop worry and rumination (Brosschot, Gerin, Thayer, 2006) and as such prevent prolonged stress responses and contribute to well-being (Sonnentag, 2012; Sonnentag & Fritz, 2015). We expected:

Hypothesis 3: Participants who are able to psychologically detach from study during the exercise sessions show a larger improvement in their weekly trajectories of well-being than participants who are less able to psychologically detach from study during these sessions

Methods

Design

Data presented in the current paper are part of a two-arm parallel-group randomized controlled trial examining if a six-week exercise intervention was superior to wait list in reducing study-related fatigue among university students. The study was approved by the Ethical Commission Social Sciences of the University (registration number: ECSW2013-1811-142) and the complete design of this trial was registered in the Netherlands Trial Register (registration number: NTR4412). The pre- and post-intervention results can be found elsewhere (see De Vries, Van Hooff, Geurts & Kompier, 2016). We showed that the intervention was effective to reduce study-related fatigue, and to increase sleep quality and indicators of cognitive functioning (De Vries, Van Hooff, Geurts & Kompier, 2016). Details relevant to the present analysis are given below.

Participants and procedure

Participants were university students. They were recruited via short talks during lectures, social media, flyers, and the Radboud University's Research Participation System. Students were eligible to participate when they i) experienced high levels of fatigue, determined by high scores (i.e., ≥ 2.2) on the Emotional Exhaustion Scale of the Utrecht Burnout Scale for Students (UBOS-S; Schaufeli et al., 2002; Schaufeli & Van Dierendonck, 2001) and high scores (i.e., ≥ 22) on the Fatigue Assessment Scale (FAS; De Vries, Michielsen, Van Heck & Drent, 2004), ii) did not engage in regular exercise for more than one hour a week, iii) did not receive psychological or pharmacological treatment for fatigue, iv) were not addicted to drugs, v) did not have a medical cause for their fatigue, and vi) did not have physical problems that prevented them from exercising regularly.

A total of 99 participants were included in the study. Fifty were randomly allocated to the exercise intervention and 49 to the wait list. The mean age of participants was 20.86 years (*SD*= 2.30), and 80.8% was female. Of the participants 72.7% was Dutch and 27.3% German. Students studied on average 26.8 hours a week (*SD* = 11.61), and generally liked their study (*M* = 7.86 on a 10-point scale, *SD* = 0.96). Almost half of the participants (43.3%) had a part-time job next to their study, on which they spent on average 7.84 (*SD* = 4.75) hours a week. The demographic characteristics were equally distributed among conditions (see De Vries, Van Hooff, Geurts & Kompier [2016] for a flow diagram, and additional descriptives).

Exercise intervention

The exercise intervention consisted of one-hour low-intensity running sessions three times a week for a period of six consecutive weeks: twice a week in a small group under supervision of a trainer, and once on an individual basis. The focus of the intervention was on becoming physically active rather than on optimizing exercise performance. During the sessions, running was alternated with walking. Over the weeks, running duration was slowly built up and walking duration was decreased. Participants rated their expended effort of the exercise sessions in the first week as 4.98 on a 10-point scale (*SD* = 2.26), and 6.83 (*SD* = 1.33) in the last week. Evaluation forms that were completed by the trainers indicated that all supervised exercise sessions were delivered as planned. More details of the intervention can be found elsewhere (De Vries, Van Hooff, Geurts & Kompier, 2016).

Materials

Participants were measured once before (T0; on average 14.74 days [*SD* = 8.48] before running or waiting), five times during (after each week of running or waiting: T1-T5), and immediately after the intervention period (T6). Figure 5.1 provides a graphical representation of the research design and an overview of which materials at what time point were measured among participants in the exercise and control condition. All study variables were assessed by means of self-report questionnaires that took about 5 minutes a week to complete. Within the sample of 99 participants, 98.27 % of the 693 (i.e., 7 measurement points * 99 participants) questionnaires were completed.

Well-being

To adequately cover well-being, a rather broad and general concept (Diener, Oishi & Lucas, 2002), we selected six indicators of well-being. These indicators were measured among both participants in the exercise and control condition on all time points (T0 to T6). "Fatigue", "Energy, and "Stress" were used as more proximal and momentary indicators of well-being. "Health status", "Satisfaction", and "Self-efficacy" were used as global and more distal indicators of well-being (Diener et al., 2002). All indicators were assessed by means of single-item measures (De Bloom, Geurts & Kompier, 2013; Van Hooff et al., 2007), since these require minimal effort to complete, and, as such, reduce the burden placed upon participants (Bowling, 2005). Prior research has indicated that unidimensional and global constructs like the well-being indicators in this study can be validly and reliably measured by means of single-item measures (De Bloom, Geurts & Kompier, 2013; Fisher, Matthews & Gibbons, 2016; van Hooff et al., 2007). The indicators were introduced as follows: "Can you indicate with a report mark between 1 (*not at all applicable*) to 10 (*extremely applicable*) to what extent the following mental states were applicable to you last week?". The response scale from 1 to 10 was based on the familiar Dutch grade notation system. Only '1' and '10' were anchored.

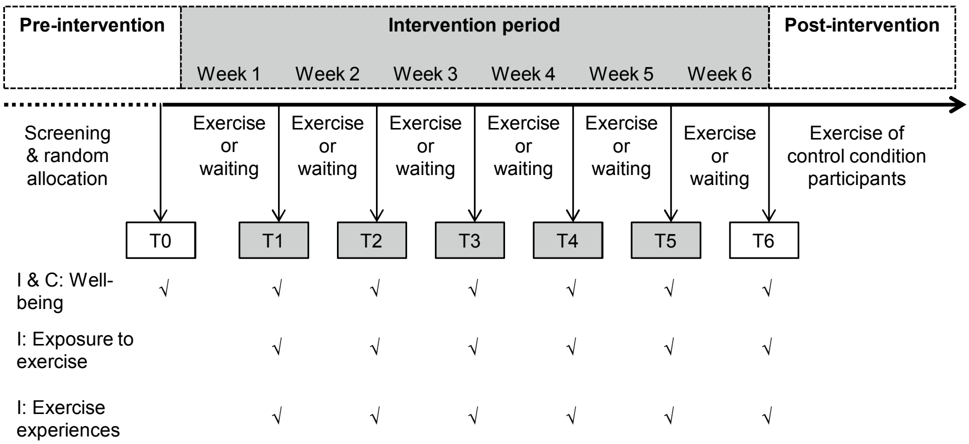

Figure 5.1. Research design (I = intervention group; C = control group)

Exposure to exercise

After each week of the intervention period, exercisers indicated whether they had engaged in the two guided running sessions and the individual session during the previous week. They also reported whether they carried out a missed guided session on their own. The sum of attended sessions (0-18 sessions) over the six weeks was used as a measure for exposure to exercise.

Exercise experiences

Exercise experiences were only measured among exercisers (T1 to T6). *Exercise enjoyment* was assessed by a self-reported single-item measure. The introduction of the item (i.e., 'enjoyable') was as follows: "Can you indicate with a report mark between 1 (*not at all applicable*) to 10 (*extremely applicable*) how you experienced last week's running sessions? The experience of the supervised and unsupervised exercise sessions was questioned separately, and combined into a mean score. *Detachment* was measured with a Dutch version of the 'Detachment' scale of the Recovery Experience Questionnaire (De Bloom, Geurts & Kompier, 2013; Sonnentag & Fritz, 2007). As this scale was originally developed for employees and covers detachment from their work, we adapted the scale for students to measure detachment from their study. An example item is: 'During the running sessions of the previous week, I forgot about my study' (1= *totally disagree*, 5= *totally agree*). Cronbach's alphas ranged between .87 (T2) and .95 (T7). The mean levels of exercise enjoyment and detachment over six weeks were used in the analyses.

Control variables

To control for the possible influence of third variables on the relationship between exercise and well-being, we controlled for students' age, gender (1= *male*; 2 = *female*), study hours a week, and weekly exam periods (0 = *no exam periods at all*; 6 = *exam periods every week*).

Statistical analyses

Multilevel analyses (Hox, 2010) in the software program MPlus 7 (Muthén & Muthén, 2012) were conducted to test our hypotheses. This analytical approach was chosen because our repeated measurements (Level 1) are nested within participants (Level 2). Multilevel analysis is able to handle observations that are not independent from each other and is also able to handle missing data (Hox, 2010). Missings were treated as missing completely at random (MCAR).

To test *Hypothesis 1* (exposure to exercise in relation to well-being), for each of the six indicators of well-being a separate model was tested. For this model, we used data only from participants in the exercise condition. The model included a random intercept for the indicator of well-being under study. This means that the intercept was allowed to vary across participants. The variable 'time' (linear effect, 7 occasions: T0 to T6) was added as a within-factor to the model. 'Exposure to exercise' was added as between-factor to the model, since this variable was computed by aggregating the number of attended exercise sessions over the six-week intervention period for each participant, hence removing within-person variance. Additionally, the model included a random slope of 'time', and a cross-level interaction term between 'time' and 'exposure to exercise'. Including this interaction allowed us to examine whether students who differ in their mean attendance rates over the six weeks differ in their rate of change in well-being over time. Lastly, we allowed the intercept to be correlated with the slope, which means a correlation between initial status and rate of growth. Significant interaction effects were interpreted using simple slopes (Preacher, Curran & Bauer, 2006).

To examine whether exercise experiences (enjoyment [*Hypothesis 2*] and detachment [*Hypothesis 3*]) of participants in the exercise condition moderated their well-being trajectories, a model comparable to the aforementioned model was tested, except that the two experiences of exercise (enjoyment and detachment) were added as between-factors to the model, and were both also modeled to interact with time (i.e., cross-level interaction). In these analyses we used each individual's mean scores of enjoyment and detachment during the six weeks of the intervention. Hence, it was investigated whether students' rate of change in well-being over time varied as a function of their average experiences of exercise during the six weeks.

To further explore the minimal exposure to exercise that is required for (statistically significant) changes in well-being to become visible, a separate model was tested for each of the six weekly indicators of well-being. We used data of both participants in the exercise and the control condition. 'Time' (7 occasions: T0 to T6) was included as within-factor in this model, and 'Condition' (0 = control, 1 = exercise) as between-factor. The model included a random slope of 'time'. This means that the trajectory over time of the respective indicator of well-being was allowed to differ across participants. Further, a cross-level interaction term between 'time' and 'condition' was added to the model. As such, it was investigated whether 'condition' explains differences in well-being trajectories. If the interaction term was significant, the effect was interpreted using simple slopes analysis (Preacher, Curran & Bauer, 2006), and 'regions of significance' (Preacher, Curran & Bauer, 2006). This latter technique allows the exact computation of boundary values where a moderator elicits statistically significant slopes.

Results

Descriptives

The means and standard deviations of the weekly indicators of well-being for each time point are presented in Table 5.1. Weekly trajectories of well-being are depicted in Figure 5.2. Descriptive statistics of exposure and exercise experiences are displayed in Table 5.2. See Appendix A for the within-person correlations (i.e., correlations between all weekly ratings of study variables; above diagonal) and the between-person correlations (i.e., correlations between each person's average rating of study variables over the course of the intervention period; below diagonal) of the study variables.

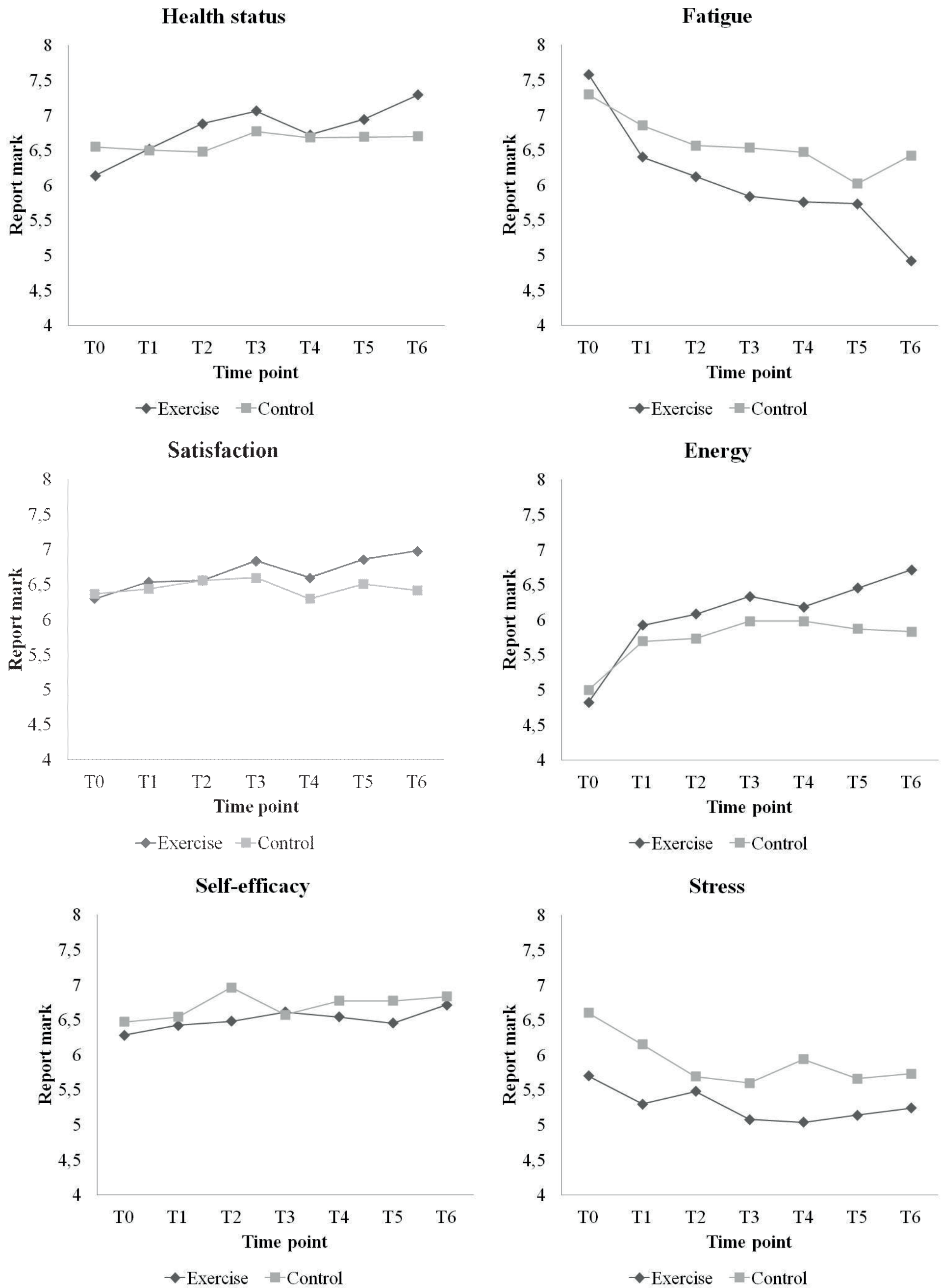

Figure 5.2 Weekly trajectories of well-being

Table 5.1. *Means (Standard Deviations) of the well-being indicators for each time point for participants in the exercise [I] and the control condition [C].*

	Pre intervention		During intervention										Post intervention	
	T0		T1		T2		T3		T4		T5		T6	
	I (*n*=50)	C (*n*=49)	I (*n*=50)	C (*n*=48)	I (*n*=50)	C (*n*=48)	I (*n*=49)	C (*n*=47)	I (*n*=50)	C (*n*=47)	I (*n*=49)	C (*n*=47)	I (*n*=49)	C (*n*=48)
Fatigue	7.58 (1.14)	7.29 (1.26)	6.40 (1.71)	6.85 (1.58)	6.12 (1.65)	6.56 (1.53)	5.84 (1.65)	6.53 (1.69)	5.76 (1.92)	6.47 (1.83)	5.73 (1.84)	6.02 (1.92)	4.92 (1.66)	6.42 (1.83)
Health status	6.14 (1.74)	6.55 (1.97)	6.52 (1.83)	6.50 (1.44)	6.88 (1.72)	6.48 (1.71)	7.06 (1.35)	6.77 (1.84)	6.72 (1.68)	6.68 (1.45)	6.94 (1.38)	6.83 (1.43)	7.29 (1.10)	6.63 (1.55)
Satisfaction	6.30 (1.57)	6.37 (1.44)	6.54 (1.37)	6.44 (1.49)	6.56 (1.50)	6.56 (1.29)	6.84 (1.30)	6.26 (1.62)	6.60 (1.55)	6.32 (1.55)	6.86 (1.21)	6.51 (1.33)	6.98 (0.99)	6.42 (1.38)
Energy	4.82 (1.21)	5.00 (1.34)	5.92 (1.50)	5.69 (1.34)	6.08 (1.50)	5.73 (1.46)	6.33 (1.57)	5.98 (1.41)	6.18 (1.49	5.98 (1.57)	6.45 (1.36)	5.87 (1.36)	6.71 (1.24)	5.83 (1.37)
Stress	5.70 (2.11)	6.60 (1.88)	5.30 (2.18)	6.15 (1.70)	5.48 (1.57)	5.69 (2.00)	5.08 (1.96)	5.60 (1.93)	5.04 (2.02)	5.94 (1.80)	5.14 (1.87)	5.66 (1.97)	5.24 (1.94)	5.73 (2.00)
Self-Efficacy	6.28 (1.58)	6.47 (1.34)	6.42 (1.21)	6.54 (1.07)	6.48 (1.43)	6.96 (1.22)	6.61 (1.10)	6.57 (1.33)	6.54 (1.34)	6.77 (1.29)	6.45 (1.54)	6.77 (1.18)	6.71 (1.08)	6.83 (0.95)

Table 5.2. *Means (Standard Deviations) for exposure to exercise and exercise experiences for each time point (only participants in the exercise condition)*

	Theoretical range	T1	T2	T3	T4	T5	T6	Overall mean (*SD*)
Exposure	0-3	2.54 (0.65)	2.63 (0.73)	2.29 (0.94)	2.27 (0.98)	2.04 (0.98)	2.41 (0.98)	2.37 (0.64)
Exercise enjoyment	1-10	7.28 (1.11)	7.31 (1.34)	7.49 (1.00)	7.05 (1.34)	7.37 (1.00)	7.45 (0.97)	7.22 (0.93)
Psychological detachment	1-5	3.46 (1.01)	3.47 (0.94)	3.69 (0.86)	3.49 (0.93)	3.73 (1.06)	3.66 (0.99)	3.63 (0.78)

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Exposure to exercise (Hypothesis 1)

During the exercise intervention, four participants dropped out (reasons: migration [*n* = 1], injuries [*n* = 3]). Overall and weekly attendance rates to the exercise sessions are presented in Table 5.2. These rates include those who dropped out (i.e., those who dropped out during the intervention continued to fill out the questionnaires). Overall, exposure to exercise was high: on average 14.27 (*SD* = 3.49) of the in total 18 exercise sessions were carried out.

As can be seen in Table 5.3, multilevel models for each indicator of well-being revealed no significant interactions between time and exposure to exercise for the outcome measures health status, satisfaction, fatigue, energy, and stress (all p values > .05). This means that the trajectories of these indicators during the intervention period did not differ as a function of exposure to exercise. The interaction between time and exposure to exercise did reach significance for self-efficacy, though (see Table 5.3), in support of *Hypothesis 1*. Simple slope analysis showed that high exposure (+1*SD*; i.e., 17.76 sessions) was related to an increase in self-efficacy (b= 0.14, z = 2.50, p = 0.01) over time, whereas low exposure was not (-1*SD*, i.e., 10.78 sessions; b= -0.03, z = 0.67, p = 0.50).

Minimal exposure

To determine the minimal exposure that is required to observe changes in well-being, trajectories of well-being exercisers and controls were compared. Table 5.4 depicts the results of multilevel analyses predicting the indicators of well-being for both exercisers and controls. Table 5.4 shows that the 'Time x Condition' interaction is significant for the well-being indicators fatigue, satisfaction, and energy. This means that for these indicators the trajectory over time differs between conditions. When interpreting these interaction effects, we switched the role of the predictor and the moderator as suggested by Preacher, Curran & Bauer (2006), because our moderator was dichotomous ('condition'; 0 = control, 1 = exercise). This means that we treated the continuous predictor 'time' as moderator and the dichotomous moderator 'condition' as predictor, i.e., statistically, this makes no difference. The simple slope then represents the difference in well-being between conditions at conditional values of 'time' (T0-T6; i.e., 0-6 weeks), and informed us at what point in time the effect of exercise on well-being becomes significant (i.e., at what point in time the intervention demonstrates an effect). It should be noted that the time interval between T0 and T1 consisted of a short wait period before the intervention started and one intervention week (see Figure 5.1). Consequently, interpretation of the number of weeks after which statistically difference between conditions becomes visible should be interpreted as 'intervention weeks'.

The simple slope tests of the significant interaction effects revealed that participants in the exercise condition showed a stronger decrease in fatigue over time (b = -.35, z = -7.30, p <.001), compared to participants in the control condition (b = -.16, z = -3.52, p < .001).

Table 5.3. *Parameter estimates of the multilevel models predicting indicators of well-being as a function of exercise exposure.*

	Health status		Fatigue		Satisfaction		Energy		Stress		Self-efficacy	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
Fixed effects												
Intercept	6.67**	0.96	8.00**	0.49	5.37**	0.44	4.69**	0.57	5.90**	0.86	6.47**	0.61
Time	-0.05	0.19	-0.52**	0.19	0.13	0.11	0.09	0.15	-0.09	0.21	-0.26	0.15
Exposure	-0.14	0.38	-0.39	0.22	0.43*	0.20	0.27	0.24	-0.16	0.36	-0.06	0.27
Time x Exposure	0.09	0.08	0.07	0.07	-0.02	0.05	0.07	0.06	0.01	0.08	**0.13***	**0.07**
Intercept with Slope of Time	-0.20**	0.07	0.00	0.09	-0.10*	0.05	-0.08	0.08	-0.23	0.16	-0.11	0.06
Random effects												
Intercept Variance (level-two)	1.61**	0.46	0.24	0.36	1.13**	0.30	0.79	0.52	1.74*	0.70	1.11**	0.36
Slope of Time Variance (level-two)	0.03	0.02	0.03	0.03	0.01	0.10	0.01	0.01	0.08	0.04	0.03*	0.01
Residual Variance (level-one)	1.60**	0.25	2.20**	0.26	1.14**	0.16	1.48**	0.21	2.40**	0.30	0.90**	0.17

Note. Unstandardized estimates and standard errors. Est = Estimate; SE = Standard Error.
Relevant effects are in bold.
* $p < .05$, ** $p < .01$ (two-tailed)

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Table 5.4. *Parameter estimates of the multilevel models predicting the six indicators of well-being for both exercisers and controls.*

	Health status		Fatigue		Satisfaction		Energy		Stress		Self-efficacy	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
Fixed effects												
Intercept	6.54**	0.19	7.06**	0.14	6.40**	0.17	5.39**	0.15	6.28**	0.21	6.56**	0.16
Time	0.04	0.05	-0.16**	0.04	0.00	0.04	0.11**	0.04	-0.12	0.06	0.05	0.03
Condition	-0.20	0.29	0.03	0.21	-0.03	0.25	-0.06	0.23	-0.78*	0.32	-0.21	0.24
Time x Condition	0.12	0.06	**-.20****	**0.07**	**0.10***	**0.05**	**0.14****	**0.05**	0.05	0.08	0.01	0.04
Intercept with Slope of Time	-0.17**	0.06	0.04	0.05	-0.08*	0.03	-0.04	0.05	-0.20	0.11	-0.08*	0.04
Random effects												
Intercept Variance (level-two)	1.33**	0.29	0.07	0.20	1.04**	0.21	0.63**	0.28	1.40**	0.41	1.01**	0.22
Slope of Time Variance (level-two)	0.04*	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.09**	0.03	0.05	0.03
Residual Variance (level-one)	1.58**	0.17	2.24**	0.19	1.13**	0.10	1.45**	0.14	2.30**	0.20	0.82**	0.09

Note. Unstandardized estimates and standard errors. Est = Estimate; SE = Standard Error.
Relevant effects are in bold.
Condition was coded as: control condition = 0, and exercise condition = 1.
* $p < .05$, ** $p < .01$ (two-tailed)

Table 5.5. *Parameter estimates of the multilevel models predicting indicators of well-being as a function of exercise experiences.*

	Health status		Fatigue		Satisfaction		Energy		Stress		Self-efficacy	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
Fixed effects												
Intercept	4.06*	1.81	4.97**	1.39	4.59**	1.33	5.35**	1.00	5.39**	1.90	6.00**	1.39
Time	0.33	0.36	0.32	0.45	-0.10	0.27	-0.48	0.26	0.32	0.38	-0.38	0.39
Enjoyment	0.36	0.23	0.06	0.17	0.45*	0.18	0.34*	0.14	-0.13	0.22	0.20	0.13
Detachment	-0.08	0.22	0.47**	0.17	-0.40*	0.19	-0.68**	0.14	0.29	0.33	-0.31	0.22
Time x Enjoyment	-0.02	0.04	-0.01	0.05	-0.01	0.04	0.03	0.03	0.07	0.05	0.04	0.04
Time x Detachment	-0.01	0.05	**-0.17****	**0.05**	0.08	0.05	**0.14****	**0.04**	**-0.24****	**0.07**	0.04	0.06
Intercept with Slope of Time	-0.20**	0.07	0.04	0.07	-0.09	0.04	-0.03	0.06	-0.19	0.13	-0.11	0.06
Random effects												
Intercept Variance (level-two)	1.50**	0.44	0.15	0.31	0.97**	0.25	0.47*	0.39	1.69**	0.65	1.03**	0.35
Slope Variance (level-two)	0.04	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.04	0.03	0.03	0.02
Residual Variance (level-one)	1.59**	0.24	2.20**	0.26	1.12**	0.15	1.48**	0.21	2.40**	0.30	0.90**	0.17

Note. Unstandardized estimates and standard errors. Est = Estimate; SE = Standard Error.
Relevant effects are in bold.
* $p < .05$, ** $p < .01$ (two-tailed)

The regions of significance additionally revealed that the exercise and control condition started to significantly differ from each other after circa 2 weeks (1.88 intervention weeks). That is, from circa 2 intervention weeks onwards participants in the exercise intervention were less fatigued than those in the control condition. The difference between conditions at this time point was small (T2: Cohen's $d = 0.28$). Additionally, being in the exercise condition was related to a stronger increase in satisfaction (b = .10, z = 3.00, $p = .003$) and energy (b = .25, z = 6.70, $p < .001$), compared to being in the control condition (b = .00, z = -0.08, $p = .94$ and b = .11, z = 3.09, $p = .002$ respectively). Participants in the exercise condition and control condition started to significantly differ from each other after circa 4 weeks (4.25 intervention weeks) with respect to satisfaction, and after circa 3 weeks (2.84 intervention weeks) with respect to energy. The differences between conditions at these time points for satisfaction and energy were small (Cohen's *d's* = 0.18 and .24 respectively).

Exercise experiences (Hypotheses 2 and 3)

Enjoyment

In general, participants enjoyed the exercise sessions; they scored on average 7.22 on a 10-point scale ($SD = 0.93$). As can be seen in Table 5.5, no significant interactions between 'enjoyment' and 'time' were found (all p values > .05). This means that *Hypothesis 2* did not receive support.

Psychological detachment

Overall, participants were quite able to detach during the exercise sessions ($M = 3.63$ on a 5-point scale). Table 5.5 shows the results of the multilevel analyses. Significant interactions between 'detachment' and 'time' were found for the well-being indicators fatigue, stress, and energy. Simple slope analyses indicated that participants reporting high detachment (+1*SD*, i.e., $M = 4.41$) showed a larger decrease in fatigue (b = -0.43, z = -1.30, $p = 0.19$) and stress (b = -0.74, z = -1.96, $p = 0.05$) over time compared to participants reporting low detachment (-1*SD*, i.e., $M = 2.85$; b = -0.17, z = -0.47, $p = 0.64$, and b = -0.37, z = -1.05, $p = 0.30$ respectively). With respect to energy, simple slopes revealed that high detachment was related to a stronger increase in energy (b = 0.13, z = 0.54, $p = 0.59$) over time compared to low detachment (b = -0.08, z = 0.35, $p = 0.72$). We note that the simple slopes indicating high and low detachment with respect to fatigue and energy were not significant. As the significant interaction term in the model already denotes that the slopes of the lines are significantly different from each other (Dawson, 2014), and simple slopes are mainly used for interpretation (to see a difference in the steepness of a slope), this is not regarded as problematic (Dawson, 2014). To enhance interpretation, interaction plots are added as supplementary material (see Appendix B). Given that three out of six indicators of well-being were moderated by psychological detachment, *Hypothesis 3* was partly supported.

Additional analyses

For each model, we also investigated whether control variables (gender, age, study hours, exam period) affected the results. However, as this proved not to be the case, we preferred not to include these variables in the models to keep these as parsimonious as possible. Furthermore, we also investigated the effect of quadratic time terms in the models (to measure changes in the rate of growth in well-being). As we found that these terms did not affect our results, we preferred to not include them in the models. Results including covariates and quadratic time effects can be obtained from the first author on request.

Discussion

Exercise interventions bear the potential for better well-being. Outcome evaluation is essential, but not enough. We not only need to know 'what works' but also 'when, how and why' this may be the case (Durlak, 2015; Hulscher, Laurant & Grol, 2003; Murta, Sanderson & Oldenburg, 2005; Steckler & Linnan, 2002). To shed more light on the latter question, we examined to what extent two of these process factors, i.e., actual exposure and exercise experiences, were related to the development of well-being during the course of an exercise randomized controlled trial aimed at reducing fatigue among university students. We investigated i) whether actual exposure to the exercise sessions was related to differences in students' trajectories of well-being, ii) the minimally required exposure to exercise needed before well-being started to differ between the intervention condition and control condition, and iii) whether exercise experiences (enjoyment and detachment) were related to differences in well-being trajectories.

As to our first aim, in support of *Hypothesis 1*, we found that exercisers with higher exposure rates showed an increase in self-efficacy over time, while no such increase was found for participants with lower exposure. Contrary to our expectations, exposure did not affect the trajectories of the other five indicators of well-being. The high mean level and low variance in exposure level (M = 14.27 [SD = 3.49] of the in total 18 exercise sessions) may be responsible for these non-significant findings. Although nearly all participants adhered quite well to the running sessions, still differences in the development of self-efficacy over time were found between participants with higher and lower exposure rates. This finding is in accordance with previous research (McAuley, Mailey, Szabo & Gothe, 2013), and implies that, in order for improvements in self-efficacy, participants must have the opportunity and motivation to (almost) fully attend the exercise sessions. On a more general note, the overall high compliance rates indicate that participants did indeed 'take the pill' (Kristensen, 2005). Our second aim was to determine the minimal exposure to the exercise sessions that is required for significant changes in student well-being to occur. We identified the point in time at which well-being trajectories of exercisers and controls started to differentiate. We found a positive effect of exercise on fatigue from two weeks during the intervention period onwards. For energy and satisfaction, beneficial effects of exercise became visible from the end of the third week and from the fourth week onwards, respectively. Together, these results showed that effects of exercise on these indicators of well-being occur relatively early in time, yet not simultaneously. The findings might even imply a temporal sequence: first a decrease in fatigue, then an increase in energy – both rather proximal and momentary well-being indicators relevant for the sample under study (i.e., fatigued students). These improvements might have resulted in an increase in satisfaction, a global and more distal well-being indicator. The difference in timing of the effects for fatigue and energy are in line with previous research that stated that fatigue and energy are related yet not overlapping constructs (O'Connor & Puetz, 2005). For health status, we only found a marginally significant interaction effect between condition and time, suggesting that the minimal exposure needs to be longer than the six-week duration of the intervention under study. No differences between exercisers' and controls' trajectories of self-efficacy and stress were found. It may be that for these two indicators to change, participants need to take part in a longer exercise intervention. In line with this reasoning, we indeed found that self-efficacy only increased when exercisers attended all exercise sessions.

Although statistically significant differences in well-being indicators between conditions at certain time points indicate that exercisers felt better than controls from those time points onwards, these differences were small (Cohen's *d*'s between 0.18 and 0.28), and do not automatically imply that exercisers also 'felt well' in a more absolute sense (i.e., clinical meaningful change). A closer examination of the report marks at the time points where the two groups start to differ (see Table 5.1) reveals that participants in the exercise condition score 'satisfactory' grades (according to the Dutch grade system a score ≥ 5.5 is satisfactory) of energy (M = 6.33) and satisfaction (M = 6.60), but not of fatigue (M = 6.12; i.e., as this is a 'negative' indicator of well-being, this grade is not satisfactory). An almost satisfactory grade of fatigue was obtained at post-intervention (M = 4.92). Thus, although between-condition differences in fatigue trajectories are observed, this result suggests that a longer intervention duration than six weeks is needed before participants experience low fatigue in an absolute sense.

As to our third aim, results showed that trajectories of well-being did not differ depending on differences in enjoyment of the running sessions (no support of *Hypothesis 2*). This may be due to the average overall high level and low variance of enjoyment (M = 7.22 [SD = 0.93] on a 10-point scale). In fact, the level of exercise enjoyment was already generally high from the beginning of the intervention (see Table 5.2).

In line with our expectations (*Hypothesis 3*) we found that participants reporting higher psychological detachment during the exercise sessions showed a larger decrease in stress and fatigue, and a larger increase in energy compared to participants reporting lower detachment. In other words, when students gave less thought to their study during the exercise sessions, the intervention had more effect. This finding is in accordance with previous research that repeatedly showed that psychological detachment facilitates the reduction of stress and, as such, enhances well-being (Sonnentag & Fritz, 2015). We did not find that psychological detachment moderated the effect of exercise on trajectories of the three more global and distal indicators of well-being. Further research should clarify whether effects of exercise on more general expressions of well-being indeed less depend on the extent to which psychological detachment is acquired during exercise.

Limitations and future research

Four issues of the current study deserve consideration. First, the sample consisted of motivated (i.e., participants signed up themselves for the study), young, and highly educated students. These students were relatively flexible in time compared to, for instance, employees who often combine work and family responsibilities. Both the high compliance and the high enjoyment rates may (partly) be influenced by these characteristics. Future studies with more diverse samples are needed before our study's results can be generalized to a broader population, for example comprising employees.

Second, the weekly measurements of well-being were based on self-reported single-item measures. Multiple-item measures are generally considered more valid and more informative than single-item measures (Bowling, 2005). However, to minimize non-response, we deliberately chose to rely on single-item measures in this study. Given the unambiguous and unidimensional nature of our well-being indicators, we believe this choice to be justified. For such measures, it has been suggested that single-item measures are valid alternatives to multiple-item measures (Bowling, 2005; Fischer, Matthews & Gibbons, 2016; Van Hooff et al., 2007). It seems highly probable that the very low non-response in our study is related to this participant-friendly approach.

Third, although a strong design was used (i.e., random allocation, control group, multiple measurement points over time), we remain to be cautious in making causal inferences, since exercisers' well-being, exposure and experiences were measured at the same points in time. Bi-directional relationships may well exist between the variables under study. For instance, self-efficacy can be both determinant and consequence of exercise engagement (McAuley, Mailey, Szabo & Gothe, 2013), meaning that higher self-efficacy rates may also have contributed to higher attendance rates. In future research, disentangling the measurements of experiences and exposure on the one hand and well-being on the other hand may help to obtain a refined picture of how these variables are related.

Fourth, although the process factors included in our study were previously shown to be important (i.e., Kristensen, 2005; Steckler & Linnan, 2002; Murta et al., 2005; Saunders et al., 2005), other unmeasured process factors, such as other exercise experiences or the context in which the intervention is conducted, may also have played a role in the development of well-being outcomes. In future studies, other – theoretically grounded - relevant process factors may also be considered.

Fifth, we linked process factors to the development of well-being from pre to post intervention, but not to longer term intervention effectiveness. Future research may also investigate whether process factors, or possibly also participants' well-being trajectories, are related to longer term intervention effects.

Theoretical and practical implications

On a theoretical note this study highlights the importance of measuring not only outcomes but also process factors throughout the intervention period in order to arrive to a better understanding not only of 'what works' but also 'when, how and why' this may be the case. As to 'how and why', it seems that higher exposure (compliance, dose received) and higher psychological detachment during the exercise sessions contribute to intervention success. As to 'when' it becomes clear that positive changes in well-being become visible already after 2 to 4 weeks, i.e., quite early in the intervention period. However, intervention duration may need to be longer than 2 to 4 weeks to obtain well-being improvements in a more absolute sense.

There are practical implications as well. We found that the exercise sessions were often attended, and that full attendance was related to stronger effects of the intervention. These high exposure rates imply that both supervised as unsupervised running three times a week for six weeks is feasible for university students. Furthermore, overall high enjoyment rates indicated that the intervention was appreciated by participants. Together, these high exposure and enjoyment rates suggest that this exercise intervention program has the promise to be successfully implemented in practice among students with fatigue problems. We also found that beneficial effects on well-being occur relatively early in time, and that a relatively short intervention of six weeks is already effective to observe meaningful changes in well-being. This finding implies that in order to bring about improvements in well-being exercise interventions do not by definition need to be very long. This is relevant for participants, trainers, researchers, and policymakers, since the duration may affect intervention features such as costs and staffing. As an almost satisfactory fatigue score was reached after six weeks, a duration of six weeks seems to be a minimal recommendation for exercise intervention duration in practice. As psychological detachment during the exercise sessions appeared to stimulate well-being outcomes, promoting this experience may deserve special attention in future exercise interventions for student well-being. For instance, participants may be taught to direct their attention towards internal stimuli (i.e., breathing) or external stimuli (i.e., environment) in order to advance cognitive distraction.

Conclusions

This study shows that in intervention research inter-measurements during the intervention period are a valuable addition to 'traditional' pre and post measurements. Such inter-measures could include measures of compliance and experiences of the intervention. This study also shows that effects of exercise on well-being become visible relatively early in time and depend on participants' exposure to the intervention and the extent to which psychological detachment can be achieved.

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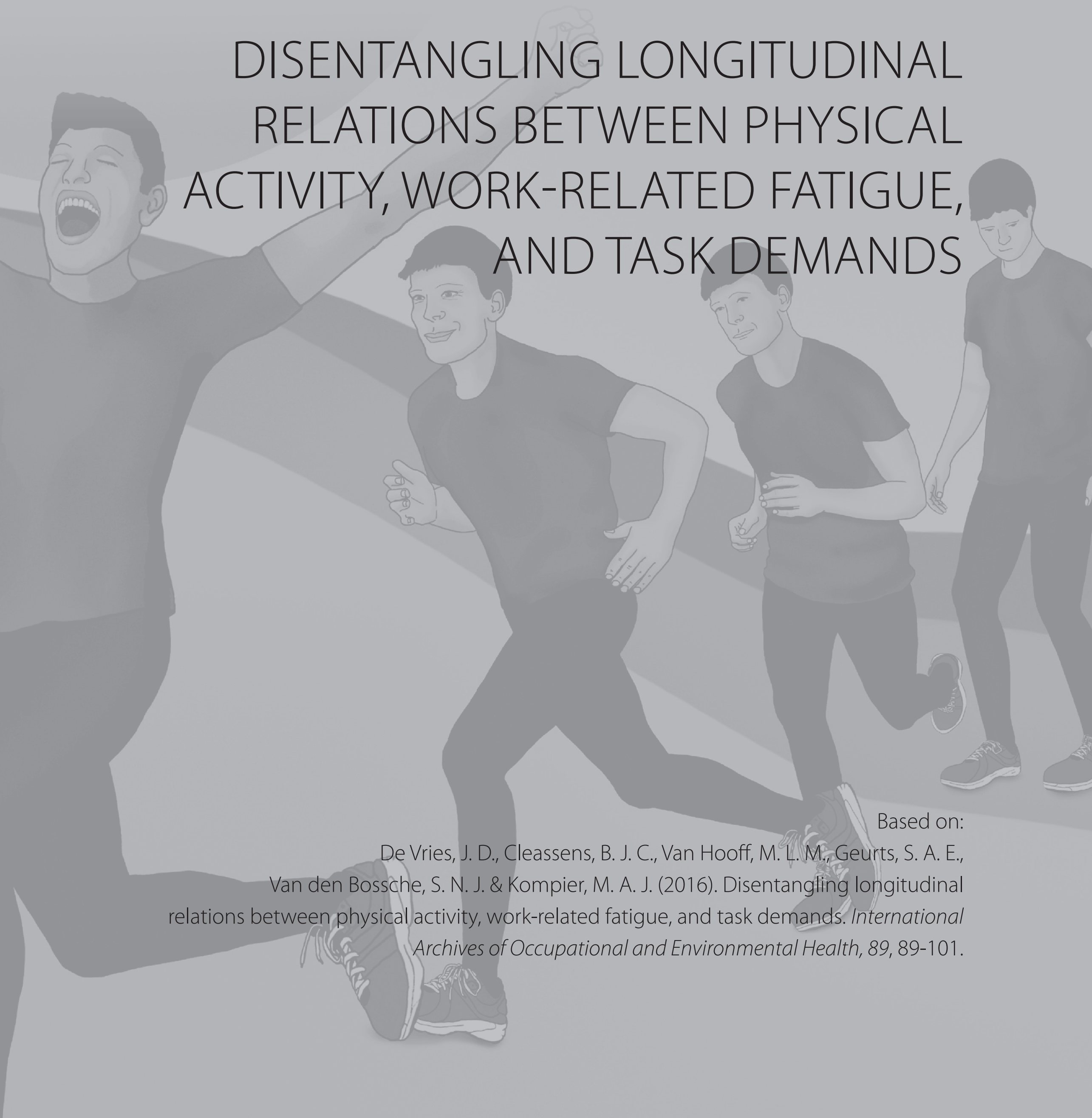
CHAPTER 6

DISENTANGLING LONGITUDINAL RELATIONS BETWEEN PHYSICAL ACTIVITY, WORK-RELATED FATIGUE, AND TASK DEMANDS



Based on:
De Vries, J. D., Cleassens, B. J. C., Van Hooff, M. L. M., Geurts, S. A. E., Van den Bossche, S. N. J. & Kompier, M. A. J. (2016). Disentangling longitudinal relations between physical activity, work-related fatigue, and task demands. *International Archives of Occupational and Environmental Health*, *89*, 89-101.

Abstract

Purpose

This longitudinal study examined 'normal', 'reversed' and 'reciprocal' relationships between: i) physical activity and work-related fatigue; and ii) physical activity and task demands. Furthermore, the effects of across time change in meaningful physical activity groups on levels of employees' work-related fatigue and task demands were studied. These groups were based on employees' compliance with the international physical activity norm.

Methods

Two waves with a one-year time lag of a national representative survey on the quality of work, health and well-being among Dutch employees were used (N=2275). Longitudinal effects were tested using Structural Equation Modeling. Meaningful physical activity groups were compared using group-by-time analysis of covariance.

Results

Support was found for reciprocal relations between physical activity and work-related fatigue. It was found that an increase in physical activity is associated with a decrease in work-related fatigue over time, and that an increase in work-related fatigue is associated with a decrease in physical activity over time. No significant longitudinal relations were found between physical activity and task demands. Employees whose compliance with the physical activity norm changed over time showed fairly stable levels of work-related fatigue and task demands.

Conclusion

The current findings provide evidence for the potential role of physical activity in the prevention and reduction of work-related fatigue. However, results also indicate that fatigued workers, who would benefit most from physical activity, are less physically active. Our results further indicate that relying on changes in compliance to the physical activity norm may not be the most suitable way to examine changes in work-related fatigue.

Introduction

There is a growing body of evidence that physical activity is an effective remedy against mental health problems (Conn, 2010; Cooney et al., 2013). As a substantial proportion of mental health problems is work-related (estimated at 22%; EWCS, 2012; Niedhammer, Sultan-Taieb, Chastang, Vermeylen & Parent-Thirion, 2014), it is valuable to examine the potential of physical activity to reduce such problems. Although previous studies do point to negative associations between physical activity and, for example, work-related fatigue (e.g. Bernaards et al., 2006; Carson, Baumgartner, Matthews and Tsouloupas, 2010), job stress (Van Rhenen, Blonk, Van Der Klink, Van Dijk & Schaufeli, 2005) and burnout (Gerber et al., 2013; Jonsdottir, Rödjer, Hadzibajramovic, Börjesson & Ahlborg, 2010), insight in the role of physical activity in the prevention and reduction of these types of problems can be advanced in at least three ways.

First, the 'bi-directional' relationships between physical activity and work-related mental health need to be addressed. Existing studies almost exclusively focused on the question how physical activity affects work-related mental health (e.g. Bernaards et al., 2006; Carson, Baumgartner, Matthews and Tsouloupas, 2010; Jonsdottir, Rödjer, Hadzibajramovic, Börjesson & Ahlborg, 2010), and ignored the possibility that employees' work-related mental health status may also influence the amount of physical activity they engage in. This is unfortunate, as it may be expected that employees who report high levels of work-related fatigue lack the resources to engage in regular physical activity. In other words, it is likely that work-related mental health and physical activity mutually affect each other.

Secondly, it has been widely established that adverse work characteristics play a key role in the aetiology of work-related mental health problems (e.g., Kompier, 2003; De Lange, Taris, Kompier, Houtman & Bongers, 2003). Therefore, to obtain a complete picture of the potentially beneficial role of physical activity for employee health and well-being, paying attention to their work environment is of vital importance. Although empirical evidence shows that (certain combinations of) work characteristics are related to employees' physical activity level (Fransson et al., 2012; Kouvonen et al., 2013), the directionality of these associations is still not well understood.

Third, previous research on the associations between physical activity, work, and mental health was mainly cross-sectional in nature, and the few longitudinal studies that exist did not take into account that for some employees a change in their level of physical activity may have been 'meaningful' (e.g. from considerably high levels to considerably low levels), whereas others report a stable (high or low) level of activity over time. It is therefore valuable to closely examine meaningful subgroups that differ in their initial levels and course of physical activity over time (i.e. "stability and change paradigm"; De Lange, Taris, Kompier, Houtman & Bongers, 2002; Van Hooff et al., 2005). This paradigm can provide more insight in what changed levels of physical activity mean for levels of work-related mental health and work characteristics.

In this study we aim to enhance insight in the association between physical activity and work-related mental health by addressing these three issues. To these purposes, we used a two-wave longitudinal full panel design with a one-year time interval of a survey on the quality of work, health and well-being among Dutch employees. We focused on work-related fatigue as an indicator of work-related mental health problems, as work-related fatigue is the most commonly reported element of burnout (Maslach, Schaufeli & Leiter, 2001) and prevalent among the working population (i.e. estimated at 18% in Europe; Milczarek, Schneider & González, 2009). In addition, based on Karasek's (1979) Job-Demands-Control Model, we focused on 'quantitative task demands' as an indicator of work characteristics. Task demands refer to the degree to which work requires employees' effort (Hockey, 2013), for instance, working fast and performing a lot of work. Finally, we defined physical activity as an activity that requires (at least moderate intensity) physical effort (WHO, 2010).

Physical activity and work-related fatigue

Although physical activity requires physical energy and physical recovery (Ament & Verkerke, 2009), it can also deliver 'mental' energy and reduce feelings of (work-related) fatigue (e.g. Bültmann et al., 2002; Lindwall et al., 2013). The exact working mechanisms underlying these observed associations are still unclear (Puetz & Herring, 2013). Both biological and psychological hypotheses have been proposed. Concerning the former, endorphin or monoamine hypotheses state that physical activity results in changes in certain neurotransmitters (e.g. endorphin) that are associated with feelings of energy, but the evidence is still weak (Dishman & O'Connor, 2009). Further, by means of regular physical activity the body is "toughened up" and is better able to handle (psychological) stress (Sothman, Buckworth, Claytor, Cox, White-Welkley & Dishman, 1996). This results in lower bodily reactions due to (work) stress (i.e. lower stress reactivity; Wipfli & Ramirez, 2013) and faster bodily recovery after being exposed to (work) stress (i.e. faster stress recovery; Spalding et al., 2004). Several other biological processes have been proposed as well, see for an overview Dishman et al. (2006).

With regard to psychological hypotheses, it has been proposed that physical activity increases people's self-efficacy (Craft, 2005), generates positive feelings about the self (Feuerhahn, Sonnentag & Woll, 2014), and creates a more positive body image (Campbell & Hausenblas, 2009). Physical activity may also generate energy by providing people the opportunity to distract themselves from negative stimuli, such as rumination about work (i.e. 'psychological detachment', Sonnentag, 2012; distraction hypothesis, Leith, 1994), and instead, shift towards more pleasant stimuli (Tian & Smith, 2011).

In line with these proposed beneficial effects, cross-sectional studies indeed show negative associations between physical activity and work-related fatigue (Carson, Baumgartner, Matthews & Tsouloupas, 2010; Mollart, Skinner, Newing & Foureur, 2013).

The few available longitudinal (Bernaards et al., 2006; Lindwall et al., 2013) and intervention studies (e.g. Gerber et al., 2013; Proper et al., 2003; Tsai et al., 2013; Van Rhenen, Blonk, Van Der Klink, Van Dijk, Schaufeli, 2005) show comparable relationships. Also, diary studies indicate that physical activity can decrease work-related fatigue on a daily level (Nägel & Sonnentag, 2013; Rook & Zijlstra, 2006).Thus, based on previous theory and empirical findings, we hypothesize:

Hypothesis 1a: Higher physical activity levels are associated with lower levels of work-related fatigue one year later

The opposite relationship between physical activity and work-related fatigue may exist as well: employees who experience high levels of work-related fatigue may be less physically active. Generally, fatigue is seen as an adaptive phenomenon: it is a signal to stop a certain task (before damage occurs) and is therefore associated with people having a lower tendency to start or complete tasks, in particular when a task requires a high level of effort (Hockey, 2013). As physical activity is effortful, it can be assumed that work-related fatigue will negatively affect the extent to which employees engage in this type of activity. In support of this assumption, scarce available empirical evidence shows that employees experiencing higher levels of work-related fatigue reported lower levels of physical activity (Ahola et al., 2012; Gorter, Eijkman & Hoogstraten, 2000). Based on the rationale that fatigue is associated with a tendency to avoid physical activity due to the effort this requires, we propose:

Hypothesis 1b: Higher levels of work-related fatigue are associated with lower levels of physical activity one year later

Physical activity and task demands

Employees' level of task demands at work may negatively affect the extent to which they engage in physical activity. First, high tasks demands may deplete personal (e.g. self-regulatory, Nägel & Sonnentag, 2013; Sonnentag & Jelden, 2009) and other resources (e.g. time, due to commuting or long working hours) that are needed to engage in physical activity. Furthermore, based on the perseverative cognition hypothesis (Brosschot, Gerin & Thayer, 2006), it can be expected that employees with higher task demands at work stay cognitively preoccupied with work during off-job time, which prolongs their physiological activation after work. It has been found that this inability to cognitively 'switch off' from work is associated with less personal control over leisure time (Cropley & Purvis, 2003), making it more difficult to engage in physical activity. Indeed, the scarce available research shows a negative association between task demands and levels of physical activity (Fransson et al., 2012; Kouvonen et al., 2013; Payne, Jones & Harris, 2002). Based on these theoretical notions and empirical findings, we expect:

Hypothesis 2a: Higher levels of task demands are associated with lower levels of physical activity one year later

One could also argue that employees' physical activity level influences perceived task demands at work. An explanation for this association is that physical activity enhances individuals' (physiological, psychological, and cognitive) health, and hence increases employees' ability to handle demands during the workday, as they require less effort (cardiovascular fitness hypothesis, e.g. Colcombe & Kramer, 2003). In other words, physical activity may lead to increased (physiological, psychological, and cognitive) capacity to cope with the demands at work. Indeed, research indicates that physical activity can contribute to employees' capacity to perform their assigned tasks (Arvidson, Borjesson, Ahlborg, Lindegard & Jonsdottir, 2013). Research has also shown that regular physical activity is associated with mastery experiences and increases in self-efficacy (Craft, 2005). Increased self-efficacy may be transferred to the work domain, resulting in employees feeling more competent to meet the task demands at work (Feuerhahn, Sonnentag & Woll, 2014; Rook & Zijlstra, 2006). Consequently, they may experience their tasks as less demanding. Thus, based on the idea that physical activity may increase employees' capacity to cope with work demands and therefore causes a shift towards a more positive evaluation of these demands, we hypothesize:

Hypothesis 2b: Higher levels of physical activity are associated with lower levels of task demands one year later

Meaningful subgroups based on physical activity norm

To get further insight into the role of physical activity in relation to work-related mental health and work-characteristics, it is worthy to examine 'meaningful' subgroups that differ in their initial levels and course of physical activity over time (cf. De Lange, Taris, Kompier, Houtman & Bongers, 2002; Van Hooff et al., 2005). Therefore, in the present study, we examine two groups of employees who differ in their starting points and courses over time regarding their engagement in physical activity. To create these meaningful subgroups, we rely on the international norm for physical activity developed by the World Health Organization (WHO, 2010), which states that people of 18 years or older should engage in at least 30 minutes of moderate-intensity physical activity on at least five days a week (in bouts of minimally 10 minutes a time) to stay healthy (Hildebrandt, Chorus & Stubbe, 2010). The two groups comprise: i) those employees who do not comply with the physical activity norm at the first time, but do so at the second time and (i.e. 'upward': indicating a beneficial change); and ii) those employees who comply with the exercise norm at the first time, but do not at the second time (i.e. 'downward': indicating an unfavourable change). We expected – in accordance with previous hypotheses – that compliance with the physical activity norm is related to lower levels of work-related fatigue and task demands:

Hypothesis 3a: Employees in the upward physical activity group (i.e. 'low-high') report a decrease in work-related fatigue and task demands one year later

Hypothesis 3b: Employees in the downward physical activity group (i.e. 'high-low') report an increase in work-related fatigue and task demands one year later

Methods

Sample

This study was based on a two-wave full panel design with a one-year time lag. The participants were part of the TNO-Netherlands Working Conditions Cohort Study in 2008 and 2009 (NWCCS; Koppes, De Vroome, & Van den Bossche 2010), a survey focused on quality of work, health, and well-being of Dutch employees (self-employed were excluded from the sampling framework). A total of 7909 employees (76.10% of the initial approached employees in 2008) filled out the questionnaire in both 2008 and 2009. We selected employees who worked fulltime (≥36 hours a week), to ensure a sufficient exposure to task demands at work. This restriction reduced our sample size to 3583 employees. Furthermore, we excluded employees who worked in physically demanding jobs, because these jobs generally require 'unhealthy physical activity', such as lifting and pushing, which has already been found to be related to unfavourable health outcomes (e.g. Trinkoff, Storr, Lipscomb, 2001). Hence, we only included employees who answered 'no' to the question 'Do you perform work in which you have to put strength, such as pushing, lifting, pulling, hauling, or do you use tools and equipment in which you have to put strength?' (1 = *yes*, *regularly*, 2 = *yes, sometimes*, 3 = *no*). This exclusion criterion further reduced our sample size to 2275 employees. Of this final sample (*N* = 2275, 28.8% of the original sample), 75.3% were male (M_{age} 45.8, *SD* = 10.0) and 24.7% female (M_{age} = 39.9, *SD* = 11.4). This distribution differed from the original sample in which 48.3% was male (M_{age} 46.3, *SD* = 10.9) and 51.7% was female (M_{age} 42.9, *SD* = 11.2). Mean working hours of the final sample were 38.4 (*SD*= 3.1) and mean working days were 4.9 (*SD* = 0.5). The employees of the final sample were mainly well educated (60.3% higher professional education) and this differed from the original sample (42.8% higher professional education). Selected employees primarily worked in the area of business services (19.3%), public administration (17.5%), industry (14.6%) and education (9.9%). These figures were comparable with those in the original sample, except that much more employees in the original sample worked in a health care setting (23.0%) compared to the final sample (8.2%).

Materials

Task demands were measured with a 4-item scale (e.g. 'Do you have to work fast?'; 1 = *never*, 2 = *sometimes*, 3 = *often*, 4 = *always*) that was derived from a Dutch version of the Job Content Questionnaire (JCQ; Houtman, 1995; Karasek et al., 1998). The reliability of the scale was high for both waves (Cronbach's α =.86 in 2008 and .85 in 2009 respectively).

Physical activity was assessed with the following question: 'On how many days a week are you normally physically active during at least 30 minutes a day (only count physical activity that is equally demanding as brisk walking or biking. Activities shorter than ten minutes do not count) - during your work and free time together?' Participants indicated how many days they complied with a minimum of 30 minutes of physical activity (*0-7 days*). This item was based on international standards for physical activity (WHO, 2010), which state that people ≥18 years of age should engage in at least 30 minutes of moderate-intensity physical activity minimally five days a week (in bouts of minimally 10 minutes a time) to stay healthy.

Work-related fatigue was measured with the 5-item "exhaustion"-subscale of the Dutch version of the Maslach Burnout Inventory (Utrechtse Burnout Scale [UBOS] Schaufeli & Van Dierendonck, 2000). A typical item is: 'I feel burned out from my work' (0 = *never*, 6 = *every day*). The reliability of the scale was high for both waves (Cronbach's α =.87 in 2008 and .88 in 2009 respectively).

Control variables

Age, gender, education, working overtime and working irregular hours, measured at T1, were included as control variables. Gender was coded as 1= *male* and 2 = *female*. Education was coded as 1 = *low*; 2 = *intermediate*; 3 = *high professional education*. Working overtime was assessed as overtime hours, using the following question: 'On average, how many hours a week do you work overtime?' (paid and unpaid work; include work you execute at home; don't include your commuting time). For working irregular hours, a variable was computed, in which employees who had no irregular work were classified as '1', and employees who worked at night, in the evening, in the weekend or had shift work were classified as '2'.

Statistical approach

Descriptive statistics (means, standard deviations, percentages, and correlations) were calculated in order to study the prevalence of task demands, physical activity, and work-related fatigue for 2008 (T1) and 2009 (T2). Additionally, it was observed whether compliance with the physical activity norm is related to (high levels of) work-related fatigue, and task demands. Next, two steps were taken to test our hypotheses.

Across-time relationships

To test Hypotheses 1a and 1b, Structural Equation Modelling (SEM) was performed using LISREL version 9.1 (Jöreskog & Sörbom, 1993). SEM was used because this technique allowed us to test reciprocal relationships between constructs. To investigate the associations between physical activity and work-related fatigue (*Hypotheses 1a* and *1b*), four models were compared to each other. The first model (M1; no causation) included lagged effects from physical activity at T1 to physical activity at T2, and from work-related fatigue at T1 to work-related fatigue at T2. Age, gender, education, working overtime, and working irregular hours were added as covariates to this model and were modelled to be related to physical activity and work-related fatigue at T1. The second model (M2; normal causation) resembled M1, but also included a path from physical activity T1 to work-related fatigue T2. The third model (M3; reversed causation) resembled M1, but now included a 'reversed' path from work-related fatigue T1 to physical activity T2. The fourth model (M4; reciprocal causation) resembled M1 and additionally included the paths of M2 and M3 so that reciprocal relationships between physical activity and work-related fatigue were investigated. The fit of the four models was compared using Chi-Square difference tests, the Comparative Fit Index (CFI), the Non-Normed Fit Index (NNFI), the Adjusted Goodness of Fit Index (AGFI), and the Root Mean Square Error of Approximation (RMSEA) (Bentler & Bonett, 1980). Model fit was considered acceptable if the NNFI, CFI and the AGFI were ≥ 0.90 and RMSEA was ≤ 0.08 (Marsh, Hau & Wen, 2004).

To test *Hypotheses 2a* and *2b* (associations between task demands and physical activity), similar analytical steps were used, meaning that again four models were compared with each other. As we entered variables measured on T1 as a predictor into the analyses, we controlled for T1 – T2 stability effects. As a result, the results of SEM reflect *changes* between T1 to T2 of respectively physical activity, task demands, and work-related fatigue.

Subgroup analyses

We investigated whether changed levels of compliance with international standards of physical activity were related to accompanying changes in levels of task demands and work-related fatigue (*Hypothesis 3a* and *3b*). Therefore, for T1 and T2, two groups were created based on employees' physical activity level. If employees were physically active for at least 30 minutes a day on less than five days a week, they were classified as 'low' (i.e. not meeting the physical activity norm). If employees were physically active at least 30 minutes on five days or more, they were classified as 'high' (i.e. meeting the physical activity norm).

To test the hypotheses, employees were incorporated in a 'low-high' (non-compliance with the norm at T1 and compliance with the norm at T2) or 'high-low' (compliance with the norm at T1 and non-compliance with the norm at T2) group. After that, we conducted a 2 (group: 'low-high' versus 'high-low') x 2 (time: T1 versus T2) ANCOVA with repeated measures on time (RM-ANCOVA) for continuous measures of work-related fatigue and task demands respectively, and focused on 'group x time', 'time', and 'group' effects. We controlled for age, gender, education, working overtime, and working irregular hours.

Results

Descriptive statistics

The means and standard deviations of study variables at both time points are presented in Table 6.1. On average, participants were physically active for at least 30 minutes on a moderate intensity on four days a week (T1: *M*= 3.98; T2: *M*= 4.09). Further inspection of our data revealed that 43.9% complied with the physical activity norm at T1 and 45.9% at T2. This is lower than a representative sample in the Netherlands, in which 58% of the population complies with the physical activity norm (Hildebrandt et al., 2013). Most participants reported low levels of work-related fatigue (at T1, 12.4% reported high [i.e. higher than the cut-off score of 2.2, see Schaufeli & Van Dierendonck, 2000] levels of work-related fatigue, and at T2 this was 12.2%). Furthermore, participants displayed relatively high levels of task demands with a mean of 2.44 for T1 and a mean of 2.42 for T2, implying that most employees experienced task demands more frequently than 'sometimes'.

Table 6.1 shows that the core variables under study remain relatively stable between T1 and T2, as indicated by T1-T2 correlations of .65 (for physical activity), .67 (for work-related fatigue), and .68 (for task demands). The pattern of correlations was in the expected direction of our hypotheses, both cross-sectional and across-time. A closer examination of compliance with the physical activity norm in relation to high levels of work-related fatigue reveals that at T1, 13.8% of employees who complied reported high work-related fatigue (≥2.2), compared to 10.8% who did not comply. For T2, these figures were 13.0% and 11.4%, respectively. Furthermore, at T1, 50.8 % of employees who complied with the physical activity norm reported high levels of task demands (i.e. a mean score of ≥ 2.5 was considered as 'high', indicating that demands were more frequently experienced than 'sometimes'), compared to 44.7% who did not comply. At T2, these figures were 50.3% and 41.9% respectively.

Table 6.1. *Means, standard deviations (SD), and correlations among study variables (N=2275).*

Variable	*M* / Frequency	*SD*	Theoretical range	1	2	3	4	5	6	7	8	9	10
1. Gender[1]	1) 75.3% 2) 25.7%		1= male; 2= female										
2. Age[1]	44.34	10.66	19-65	-.24**									
3. Education[1]	1) 8.9% 2) 30.8% 3) 60.3%		1= low; 2=intermediate; 3= high	.05*	.16**								
4. Hours working overtime[1]	4.01	4.44	0-38	-.08*	.03	.14**							
5. Irregular working hours[1]	1) 80.8% 2) 19.2%		1=no irregular hours; 2= irregular hours	.05*	-.01	.07**	.24**						
6. Task demands T1	2.44	0.60	1-4	-.01	.00	.20**	.35**	.08**					
7. Task demands T2	2.42	0.60	1-4	.08	-.03	.21**	.31**	.06**	.68**				
8. Work-related fatigue T1	0.95	1.01	0-6	.05*	-.03	.08**	.04	.01	.28**	.22**			
9. Work-related fatigue T2	0.97	1.03	0-6	.02	-.04	.07**	.04	-.01	.24**	.28**	.67**		
10. Physical activity T1	3.98	2.14	0-7	.03	.09**	-.02	-.12**	-.04	-.06**	-.07**	-.08**	-.08**	
11. Physical activity T2	4.09	2.10	0-7	.03	.13**	-.03	-.10*	.00	-.07**	.08**	-.09**	-.08**	.65**

[1] Score at T1.
* p <.05 ** p <.01

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Across-time relationships

Fit indices of the four models that were compared to test *Hypotheses 1a* and *1b* are presented in Table 6.2. Model 1 fitted the data well, with significant paths between work-related fatigue measured at T1 and at T2 (β = .53), and between physical activity measured at T1 and T2 (β = .44). Model 2 also fitted the data well, and fitted significantly better than Model 1 (see Table 6.2 for model comparisons). This model reveals a significant negative association between physical activity T1 and work-related fatigue T2 (β = -.05). Also Model 3 fitted the data well, and fitted better than Model 1. This model shows a significant negative association between work-related fatigue T1 and physical activity T2 (β = -.08). Table 6.2 shows that Model 4 – including reciprocal associations between physical activity and work-related fatigue – has an acceptable fit as well, and that this model fitted better than both Model 2 and Model 3. Consequently, we chose Model 4 as the best fitting model (see Figure 6.1 for a graphical representation). This model shows that physical activity at T1 is associated with a decrease in work-related fatigue from T1 to T2, thus supporting *Hypothesis 1a*. Further, the model shows that work-related fatigue is associated with a decrease in the level of physical activity from T1 to T2, thus supporting *Hypothesis 1b*. Additionally, some covariates were significantly related to the constructs of interest at T1: working overtime (β = -.09), and age (β = .05), were related to physical activity; and working overtime (β = .04) was related to work-related fatigue.

Table 6.2. *Fit indices of Structural Equation Models for the longitudinal associations between physical activity and work-related fatigue, and physical activity and task demands. The models are controlled for gender, age, education, working overtime, and working irregular hours.*

Model [a]	χ^2	df	NNFI	CFI	AGFI	RMSEA	Model Comparison	Δ*df*	$\Delta\chi^2$
Physical activity and work-related fatigue (*H1a* & *H1b*)									
M1 (no causation)	57.48	12	0.92	0.97	0.98	0.04			
M2 (normal causation)	49.62	11	0.93	0.98	0.98	0.04	M1 vs. M2	1	7.86**
M3 (reversed causation)	39.39	11	0.95	0.98	0.98	0.03	M1 vs. M3	1	18.09**
M4 (reciprocal causation)[a]	**31.65**	**10**	**0.95**	**0.99**	**0.99**	**0.03**	M2 vs. M4	1	17.97**
Physical activity and task demands (*H2a* & *H2b*)									
M1 (no causation)	58.05	12	0.93	0.98	0.98	0.04			
M2 (normal causation)	54.93	11	0.93	0.98	0.98	0.04	M1 vs. M2	1	3.12
M3 (reversed causation)	57.12	11	0.93	0.98	0.98	0.04	M1 vs. M3	1	0.93
M4 (reciprocal causation)	53.99	10	0.92	0.98	0.98	0.04	M2 vs. M4	1	0.94

[a] Bold: best fitting model
* p <.05 ** p <.01

To test *Hypotheses 2a* and *2b,* again four models were compared. The fit indices and model comparisons of the four models are presented in Table 6.2. Model 1 fitted the data well, with significant paths from physical activity T1 to physical activity T2 (β = .44), and from task demands T1 to task demands T2 (β = .56). None of the extended models fitted better than Model 1, and therefore *Hypothesis 2a* (high levels of task demands are associated with lower levels of physical activity one year later) and *Hypothesis 2b* (higher physical activity levels are associated with lower levels of task demands one year later) were not supported.

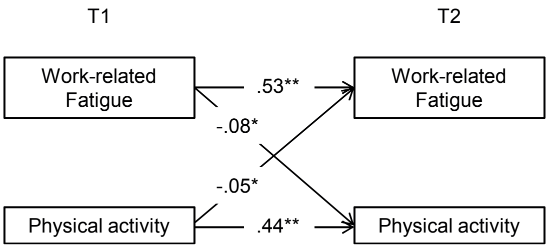

Figure 6.1. Reciprocal model (Model 4) between work-related fatigue and physical activity (*Hypothesis 1a* and *1b*), controlled for gender, age, education, working overtime, and irregular working hours. Standardized paths (β's) are displayed.
* *p* <.05 ** *p* <.01

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Subgroup analyses (Hypotheses 3a and 3b)

The estimated means and standard deviations of work-related fatigue and task demands for the different physical activity groups are presented in Table 6.3. The means and standard deviations of the stable physical activity groups (i.e. compliance at both times and non-compliance at both times) are also depicted in Table 6.3 to provide a complete picture what stable and changed physical activity levels mean for work-related fatigue and task demands. As can be seen in Table 6.3, most participants displayed fairly stable physical activity levels, and relatively few participants changed with regard to compliance with the physical activity norm: 12.1% of participants showed an upward change (n = 258), and 10.6% showed an downward change (n = 225). The RM-ANCOVA revealed that there was no significant interaction between 'group' and 'time' for work-related fatigue ($F(1,476) = .74$, $p = .391$) and task demands ($F(1,476) = .09$, $p = .662$), meaning that changes in levels of work-related fatigue and task demands over time did not differ between the upward and downward physical activity group. The RM-ANCOVA also showed no effect of 'time' on work-related fatigue ($F(1,476) = .02$, $p = .893$), and task demands ($F(1,476) = .07$, $p = .793$), meaning that levels of work-related fatigue and task demands did not change over time. No effect of 'group' was found ($F(1,476) = .04$, $p = .850$), meaning that the groups did not differ on their mean levels of work-related fatigue and task demands. All in all, no support was found for *Hypotheses 3a* and *3b*.

Table 6.3. *Means and standard deviations of work-related fatigue and task demands for the different meaningful physical activity groups, adjusted for age, gender, education, working overtime, and irregular working hours.*

Physical activity group		Work-related fatigue					Task demands				
		T1		T2		*D*[d]	T1		T2		*D*
	n[a]	*M*	*SD*	*M*	*SD*		*M*	*SD*	*M*	*SD*	
Low T1-Low T2[b] (Stable low)	913	1.04	0.91	1.05	0.93	0.01	2.49	0.52	2.47	0.49	-0.04
High T1-High T2[c] (Stable high)	724	0.84	1.17	0.90	1.20	0.05	2.43	0.65	2.39	0.65	-0.06
Low T1-High T2 (Upward change)	258	0.98	1.03	0.95	1.06	-0.03	2.38	0.56	2.39	0.56	0.02
High T1-Low T2 (Downward change)	225	0.90	1.02	0.88	1.05	-0.02	2.39	0.56	2.42	0.56	0.05

[a] 155 missing values; [b] 'Low' = not complying with the physical activity norm (i.e. < 5 days a week 30 minutes of moderate-intensity physical activity); [c] 'High' = complying with the physical activity norm (i.e. ≥ 5 days a week 30 minutes of moderate-intensity physical activity). [d] Cohen's *D* effect size for the mean difference between T1 and T2. * p <.05 ** p <.01

Discussion

In this study, we examined longitudinal relationships between physical activity, work-related fatigue and task demands. Our goal was threefold. First, we examined possible bi-directional relationships between physical activity and work-related fatigue (*Hypotheses 1a* and *1b*). Secondly, we investigated whether employees' task demands and physical activity level mutually influence each other (*Hypotheses 2a* and *2b*). Finally, we addressed the effects of change in employees' adherence with the international physical activity norm in relation to work-related fatigue and task demands (*Hypotheses 3a* and *3b*). Table 6.4 presents an overview of support levels for this study's hypotheses.

Table 6.4. *Synthesis of evidence.*

Hypotheses		Longitudinal support
H1a	Higher levels of physical activity → Lower levels of work-related fatigue	+
H1b	Higher levels of work-related fatigue → Lower levels of physical activity	+
H2a	Higher levels of task demands → Lower levels of physical activity	-
H2b	Higher levels of physical activity → Lower levels of task demands	-
H3a	Upward physical activity group → Decrease in work-related fatigue and task demands	-
H3b	Downward physical activity group → Increase in work-related fatigue and task demands	-

In accordance with previous studies (e.g. Bültmann, Kant, Van den Brandt & Kasl, 2002; Lindwall, Gerber, Jonsdottir, Börjesson & Ahlborg, 2013), we found that higher levels of physical activity were related to lower levels of work-related fatigue one year later (*Hypothesis 1a*), although the size of this effect was relatively small. It should be noted, though, that longitudinal effects are always smaller and more difficult to detect than cross-sectional ones (Ford et al., 2014). Also, in this study, we controlled for the level of physical activity and work-related fatigue at T1 in our SEM-model. As these constructs were rather stable over time (across-time correlations r = .65 for physical activity and r = .67 for work-related fatigue), a large proportion of the variance in physical activity and work-related fatigue was already accounted for by the same indicator measured one year earlier. This means that the proportion of variance left to be explained was rather small. The association between physical activity and work-related fatigue was not supported by our subgroup-analyses, which showed that a change in compliance with the physical activity norm (*Hypothesis 3a* and *3b*) was not related to accompanying changes in work-related fatigue. This discrepancy in findings may be attributed to insufficient contrast between the two physical activity change groups. A closer examination of the data revealed that, in both groups, a notable proportion of participants reported just one or two days change in physical activity (i.e. 42.7% in the 'upward' change group, and 47.6% in the 'downward' change group changed one or two days). As a result, it may be difficult to detect intergroup differences in the development of work-related fatigue over time. Thus, within our relatively stable sample, distinguishing between subgroups based on changes in the physical activity norm may not be a sensitive enough method to capture differences in patterns of work-related fatigue over time.

Our results also support the hypothesis that employees' level of work-related fatigue was negatively related to engaging in physical activity (*Hypothesis 1b*). This could imply that being tired from work is a decisive factor for employees in whether or not to engage in physical activity. This result also implies that even the relatively low levels of work-related fatigue that were experienced by the employees in this study may already interfere with their physical activity levels. Finding reciprocal relations between physical activity and work-related fatigue may point to a downward spiral, in which more work-related fatigue is related to lower physical activity, which in turn relates to even higher levels of work-related fatigue.

Contrary to the few previous studies that addressed this association (Feuerhahn, Sonnentag & Woll, 2014; Fransson et al., 2012; Kouvonen et al., 2013; Payne, Jones & Harris, 2002; Sonnentag & Jelden, 2009), we did not find a longitudinal negative association between task demands and physical activity (*Hypothesis 2a*). Our result may be explained by the fact that task demands especially affect physical activity during leisure time and not during work time (Fransson et al., 2012; Kouvonen et al., 2013), and affect rather activities that are voluntary rather than compulsory. Unfortunately, due to the measurement of physical activity in this current study, it was unknown whether employees' physical activity entailed (voluntary) sport activities during leisure time, or that it was part of their 'daily life' (e.g. at work or during household chores). The latter types of activities are often obligatory and part of daily routines, and will thus not be easily skipped, while (voluntary) sports activities during leisure time may be more easily omitted if one's resources are depleted due to high task demands.

Also, no support was found for the idea that higher levels of physical activity are related to lower levels of task demands over time (*Hypothesis 2b*). Similarly, the upward and downward physical activity groups did not show changes in task demands over time (*Hypotheses 3a and 3b*). An explanation for these findings may be that task demands are partly 'inherent' to the job and thus cannot easily be changed. It may also be that changes in physiological, psychological, and cognitive health that can develop within a one-year time lag are too small to induce a response shift in the evaluation of task demands. Furthermore, it may be that not all types of physical activity impact task demands. For instance, one can imagine that sport activities result in mastery experiences (Craft, 2005), which reduce perceived task demands, due to an increase in self-efficacy in the work domain. For other physical activities, such as physical household activities, this association may not be found, because these may not be associated with mastery experiences. Unfortunately, again referring to the measurement of physical activity in this current study, we cannot distinguish between these different types of physical activity.

Limitations and suggestions for future research

There are seven issues concerning the current study that deserve attention. First, we exclusively relied on self-report measures in the present study. Some consider this to be a limitation, because it would result in an overestimation of the associations among variables due to common method variance. Based on his study of the potential problem of common method variance, Spector (2006) nonetheless concluded that "the popular position suggesting that common method variance automatically affects variables measured with the same method is a distortion and oversimplification of the true state of affairs" (p. 221). Besides, internal states, such as work-related fatigue can best be mapped by means of reports by those who are involved in these experiences. This notwithstanding, it would be valuable for future studies to combine self-report measures of physical activity with more objective methods, such as accelerometers or actigraphy (Prince et al., 2008).

Second, – and related to the first issue – the self-report measurement of physical activity deserves attention. In general, people often over- or underestimate their true physical activity level, for instance due to recall bias or social desirability (Prince et al., 2008). Therefore, it is likely that self-report measures in this current study do not precisely reflect employees' actual physical activity levels. In addition, participants in the current study were asked 'on how many days a week they were physically active for at least 30 minutes at a moderate intensity'. As a result, the exact total duration and frequency of employees' physical activity was unknown (e.g. when someone answers 'three days', it could be exactly 90 minutes, but also more than this amount). Also, the exact intensity of the physical activity was not known. We only knew that the physical activity was at least of moderate intensity. Intensity is important, because it may affect work-related fatigue in different ways. For instance, it has been found that physical activity at a high intensity heightens someone's fatigue and may even lead to exhaustion (Loy, O'Connor & Dishman, 2013), whereas low (Puetz, Flowers & O'Connor, 2008) to moderate intensity (Salmon, 2001) physical activity levels are related to lower fatigue. Furthermore, the type of physical activity was unknown (e.g. non-aerobic training, physical activity as part of daily life or as sport activity). Different types of physical activity could have distinct effects on work-related fatigue. There are reasons to believe that physical activity as part of household chores is not beneficial for work-related fatigue, whereas sport activities are (Demerouti, Bakker, Geurts & Taris, 2009). Based on these considerations, it is important that future studies measure the intensity (i.e. low, moderate, high), duration, frequency and type (i.e. aerobic or non-aerobic, and during leisure time or part of daily life) of physical activity (e.g. Aadahl & Jørgensen, 2003) and investigate which may benefit work-related fatigue most.

Third, also relating to the specific measurement of physical activity in the current study, we could not unravel whether employees' physical activity was performed during leisure or work time. Therefore, we chose to not include employees with potentially unhealthy physical demanding work to prevent that the association between physical activity and work-related fatigue was confounded by such unhealthy physical activity. This is unfortunate, because it has been shown that employees engaging in physical demanding work can also benefit from leisure time physical activity with regard to their health (e.g. Holtermann et al., 2013). Future research could further disentangle the associations between physical activity, work-related fatigue and task demands by explicitly examining employees with physically demanding work.

A fourth issue that needs attention is that there was relatively small across-time variation in the variables included in this study. This is reflected in the relatively high test-retest correlations over time (ranging from r = .65 to .69) and stable mean scores (see Table 6.1). This would imply that a longer time interval should be covered in order to investigate the impact of change in physical activity on work-related fatigue and task demands. Furthermore, including more time points is preferable to detect the 'true' time lag underlying the observed associations (Taris & Kompier, 2003).

Fifth, as our sample consisted of relatively healthy workers, it may well be possible that there was a restriction of range leading to an underestimation of the true relationships found in this current study. For instance, in accordance with previous studies that demonstrated negative associations between physical activity on clinical levels of work-related fatigue (Kant, Van den Brandt & Kasl, 2002; Gerber et al., 2013), the effect of physical activity on work-related fatigue found in this study might be an underestimation of the true (causal) effect. Further research is needed to investigate this.

Sixth, our selection criteria of participants resulted in a relatively small proportion of the original sample (28.8%). Although our choice of selecting full-time (≥36 working hours) employees was based on theoretical grounds, it would be interesting to see whether the relations found in our study also exist if we would have used other working hour limits. We therefore reanalyzed our data, including all employees, irrespective of their working hours. The results of these analyses (based on all employees, irrespective of their working hours) revealed a comparable pattern of results[1], which underlines the robustness of our findings. Finally, we were not able to draw firm conclusions regarding causality with respect to the observed longitudinal associations, because we could not eliminate the influence of potentially relevant third variables (Taris & Kompier, 2003). To get further insight in the causal associations between physical activity and work-related fatigue and task demands, further research is needed in the form of well designed randomized controlled trials, for instance targeting physical activity levels of employees with (clinical levels of) work-related fatigue (Proper, Staal, Hildebrandt, van der Beek & Van Mechelen, 2002).

Theoretical and Practical implications

We believe our study contributes to previous research on physical activity and employee health both theoretically and practically. To our knowledge, we were among the first to longitudinally investigate 'bi-directional' relationships between physical activity and work-related fatigue, and physical activity and task demands. By doing so, we were able to provide a basic understanding of how physical activity is related to work-related mental health and to work characteristics. Furthermore, we tried to obtain more thorough insight in these relationships by investigating how work-related fatigue and task demands develop as a function of different (i.e. changed) meaningful physical activity patterns over time, based on employees' compliance with the international physical activity standards (WHO, 2010). Even though our core variables under study proved to be rather stable during the one-year time lag of this study, and even though physical activity could have been measured more thoroughly, we were able to demonstrate that an increase in physical activity was related to a decrease in work-related fatigue over time. This highlights the importance of physical activity for the protection of employee health and well-being. But, we also demonstrated that fatigued workers, who would benefit most from physical activity, engaged less in this type of activity. Therefore, it seems important to pay attention how to motivate fatigued

1 Results of these analyses can be requested from the first author.

employees to engage in regular physical activity. For instance, evidence shows that learning to focus on the ending of a physical activity session, instead on the often unpleasant beginning of physical activity, is a potential to increase people's physical activity level (Ruby, Dunn, Perrino, Gillis & Giel, 2011). In addition, the finding that changes in adherence to international standards of physical activity were not related to accompanying changes in work-related fatigue, indicates that relying on changes in compliance with this standard may not the most suitable way to examine changes in work-related fatigue. In this respect, it is interesting to note that the dichotomous approach of the physical activity norm is currently under discussion. Although it has been shown that the physical activity norm is certainly meaningful for (mental) health (Haskell, Lee, Pate, Powell & Blair, 2007), it has been argued that a slight increase in physical activity for people who are inactive could already result in health benefits (De Sauto Barreto, 2015; Sparling, Howard, Dunstan & Owen, 2015). Thus, a dose-response approach (i.e. small incremental increases in daily physical activity) may be more appropriate than a 'threshold approach' (i.e. compliance or non-compliance) for promoting physical activity.

From a practical point of view, current findings suggest that it is valuable for employees to be physically active, in leisure time as well as during work time (Commissaris, Douwes, Schoenmaker & De Korte, 2008). Based on the demonstrated beneficial effects of physical activity, the employer can be encouraged to promote physical activity at the workplace by stimulating physically active transportation to work, designing 'active' workplaces or offering physical activity programs at work (Conn, Hafdahl, Cooper, Cooper, Brown & Lusk, 2009). Furthermore, employees should strive to make physical activity part of their daily routine, even when fatigued.

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CHAPTER 7

GENERAL DISCUSSION

The main purpose of this thesis was to advance knowledge about the extent to which exercise is effective in reducing work-related fatigue. To this purpose, three interrelated empirical studies were reported. They were reported in Chapters 2 to 6. In this last chapter, the main findings are summarized and discussed. Next, methodological considerations and future research directions are addressed. I conclude this chapter with practical implications of this work.

Discussion of main findings

The three empirical studies in this thesis contribute to knowledge about the exercise – work-related fatigue relationship by addressing three limitations in earlier research that hindered strong causal inferences: i) lack of well-designed exercise intervention studies aimed at reducing work-related fatigue; ii) lack of process evaluations in exercise intervention studies aimed at reducing work-related fatigue; and iii) lack of insight in possible 'reciprocal' causation between exercise and work-related fatigue. Below, results of the three empirical studies are considered against the background of these three limitations.

Effect evaluation of exercise intervention studies aimed at reducing work-related fatigue

Prior intervention studies already showed that exercise decreases work-related fatigue (Bretland & Thorsteinsson, 2015; Gerber et al., 2013; Lindegard et al., 2015; Tsai et al., 2013; Van Rhenen et al., 2005; except Freitas, Carneseca, Paiva & Paiva, 2014). Despite these efforts, firm causal inferences regarding the association between exercise and reductions in work-related fatigue were not possible. This was due to several methodological shortcomings: a) lack of control conditions; b) no (described) randomization procedure; c) combination of exercise and other intervention ingredients; and d) lack of intention-to-treat analyses (i.e., including all participants into the analyses, irrespective of non-compliance; Gupta, 2011). Consequently, there was a need for intervention studies that adopt a more rigorous study design to allow for stronger causal conclusions.

Against this background, we conducted two randomized controlled trial (RCT) studies. The RCT design acknowledges randomization, control condition(s), and longitudinal data collection, and therefore better allows for causal inferences (Kristensen, 2005). Our analytical approach was based on the intention-to-treat principle (Gupta, 2011), which minimizes Type 1 error (i.e., detecting an effect that is not present), helps to preserve comparable groups that are brought about by randomization, and gives insight in the extent to which intervention outcomes can be translated into practice (Gupta, 2011).

The effect evaluation of Study 1 is reported in Chapter 2. Participants were students with study-related fatigue who were still able to study. Study-related fatigue refers to fatigue resulting from prolonged study stress (Law, 2007; Schaufeli, Martínez, Marques Pinto, Salanova & Bakker, 2002), and therefore largely resembles work-related fatigue. In Study 2 (see Chapter 3: study protocol, and Chapter 4: effect evaluation) participants were employees with work-related fatigue who were still able to work. In both Study 1 and Study 2, participants were randomly assigned to either a six-week exercise intervention or a wait list control condition. This made it possible to test the effect of exercise on work-related fatigue compared to the 'natural course' of fatigue. The exercise intervention included supervised (two one-hour sessions a week) and unsupervised (one one-hour session a week) low-intensity running, for six consecutive weeks.

Study 1 showed that exercise had a small-to-moderate effect on reducing study-related fatigue (effects on overall fatigue and need for recovery). Compliance was high: on average students attended 81% of the exercise sessions. Furthermore, only 8% dropped out during the intervention. In Study 2, intention-to-treat analyses revealed no significant effect of exercise on work-related fatigue. A closer examination of participants' compliance revealed that 29% of exercisers did not start exercising or gave up exercising before the end of the intervention. In addition, 21% of the controls did not wait but increased their exercise level during the intervention period. Therefore, we also conducted per-protocol analyses (Montori & Guyatt, 2001), in which only compliant participants were analyzed. A comparison between 'true' exercisers and 'true' controls revealed that exercise had a moderate effect on reducing work-related fatigue. This result implies that exercise indeed 'works' for employees (effects on overall fatigue and emotional exhaustion), but under good circumstances (i.e., 'efficacy' of the intervention; see Gartlehner et al., 2006), i.e., when participants adhere to the intervention. This means thus that the 'efficacy' of this intervention is satisfactory, but that the 'effectiveness' of the intervention, i.e., the working of the intervention among fatigued employees in real-world practice (Gartlehner et al., 2006), can be further improved. Since we could not identify prognostic factors that were associated with non-compliance (i.e., this was unrelated to baseline outcomes and characteristics), future research should elaborate on this. Possibly, the intervention needs to be further tailored to employees' practical possibilities to enhance compliance.

The effect sizes that we found were smaller compared to earlier studies that displayed large effects of exercise on work-related fatigue (Bretland & Thorsteinsson, 2015; Gerber et al., 2013; Lindegard et al., 2015; Tsai et al., 2013; Van Rhenen et al., 2005). As earlier studies lacked a decent randomized controlled design including control conditions, adequate randomization procedures, and intention-to-treat analyses, it is likely that previous estimates of exercise intervention efficacy were biased to the positive and somewhat overoptimistic. In our studies, exercise was not only effective in reducing work-related fatigue, but also resulted in beneficial changes in secondary outcomes. Consistent across students and employees, we found improvements in sleep quality, (self-reported) cognitive functioning, work ability (note that work ability was only measured among employees), and less self-reported demands during cognitive tests. These results are in accordance with previous studies that also showed beneficial effects of exercise on such outcomes – albeit not in fatigued individuals (e.g., Arvidson, Börjesson, Ahlborg, Lindegård & Jonsdottir, 2013; Kredlow, Capozzoli, Hearon, Calkins & Otto, 2015; Smith et al., 2010). Not all included secondary outcomes improved in our studies, though. No effects were found for self-efficacy, sleep duration, (most) 'objective' indicators of cognitive functioning and objectively measured physical fitness. It is possible that a different exercise 'dose' is needed to observe differences in these outcomes (e.g., Gormly et al., 2008; Kredlow, Capozzoli, Hearon, Calkins & Otto, 2015; Smith et al., 2010).

In both studies, initial intervention effects were maintained on the longer term, i.e., until 12 weeks after the intervention. In fact, small further improvements were found in study- and work-related fatigue during the follow-up period. A note of caution is due here, since the wait list design did not allow us to compare exercisers and controls at follow-up (i.e., controls received the exercise intervention after six weeks of waiting). Nevertheless, a (considerable) part of the participants chose to engage in regular exercise during the follow-up period: 80% of the students and 43% of the employees. Especially among students, the intervention thus seemed to stimulate exercise behavior on the longer term. Objectively measured physical fitness (students) and need for recovery (employees) improved among those who engaged in regular exercise during follow-up, whereas no improvement was observed among those who did not do so.

BOX I. Effect evaluation of exercise intervention studies (Chapters 2, 3 and 4).

- Exercise reduced study-related fatigue among university students (Study 1).
- Exercise reduced work-related fatigue among employees who 'take the exercise pill' (Study 2).
- Exercise improved sleep quality, cognitive functioning and work ability (employees) in individuals experiencing study- and work-related fatigue.
- Beneficial effects of exercise were maintained at 12 weeks follow-up.
- Small further improvements were observed for those who continue exercising at follow-up.

Process evaluation of exercise interventions

Effect evaluation of intervention studies, i.e., a comparison of pre- and post-intervention outcomes, allows for an understanding of 'what works', but does not provide insight as to 'when, how and why' this may be the case (Moore et al., 2015). During an intervention period many things might happen that affect intervention outcomes, e.g., the intervention may not be delivered as intended, participants may be differently exposed to intervention ingredients, and participants may appraise the intervention in various ways (Kristensen, 2005; Moore et al., 2015; Murta, Sanderson & Oldenburg, 2007; Nielsen & Randall, 2013; Steckler & Linnan, 2002). By means of 'traditional' effect evaluation, it remains unknown whether these process factors may have influenced intervention effects. Therefore, it is possible that effects can (partly) be attributed to process factors. This implies that not only effect evaluation, but also process evaluation needs to be considered when evaluating interventions. Process evaluation opens the 'black box' to see what happened during the intervention period. It explores the implementation (i.e., the way a program is put into practice), receipt (i.e., dose and views of participants) and setting (i.e., general intervention and implementation context) of the intervention and helps in interpreting intervention outcomes (Durlak, 2015; Kompier & Aust, 2016; Murta, Sanderson & Oldenburg, 2007; Steckler & Linnan, 2002). In previous studies, process evaluation of exercise interventions for work-related fatigue has as yet received little to no attention, though.

Therefore, to better understand when, how and why exercise interventions against work-related fatigue operate, we aimed to open the 'black box' of the intervention period of Study 1 and Study 2[1]. To this end, participants were measured before, five times during and immediately after the six-week intervention period on well-being indicators and process factors. In Study 1 (see Chapter 5), six indicators of well-being among both exercisers and controls ('fatigue', 'energy', 'stress', 'health', 'satisfaction' and 'self-efficacy') were measured. Process variables were only measured among exercisers and included exposure (i.e., 'dose received') and participants' experiences of the intervention (i.e., enjoyment and psychological detachment). We investigated i) whether actual exposure to the exercise sessions was related to differences in participants' trajectories of well-being, ii) the minimally required exposure to exercise needed before well-being started to differ between the intervention and control condition, and iii) whether exercise experiences (enjoyment and detachment) were related to differences in well-being trajectories.

As to 'exposure', all participants adhered quite well to the exercise sessions. Despite this overall high exposure rate, still an increase in self-efficacy was found for students who were exposed to (nearly) all exercise sessions. This increase in self-efficacy was not found among the students with lower exposure. This finding is in accordance with previous research (McAuley, Mailey, Szabo & Gothe, 2013), and seems to imply that, in order for improvements in self-efficacy, participants must have the opportunity and motivation to (almost) fully attend the intended exercise sessions. Possibly, the overall high exposure rate and the low variance in exposure may have played a role in the absence of significant findings with regard to the other well-being indicators.

1 Results of the process evaluation of employees are not part of this thesis (manuscript in preparation).

With respect to the minimally required exposure, it was found that student-exercisers displayed lower fatigue than controls, from two weeks during the intervention period onwards. For energy and satisfaction, beneficial effects of exercise became visible from the end of the third week and from the fourth week onwards, respectively. One may consider this order as a temporal sequence: first a decrease in fatigue, then an increase in energy – both rather proximal and momentary well-being indicators relevant for the sample under study (i.e., fatigued students). These improvements might have resulted in an increase in satisfaction, a global and more distal well-being indicator. Together, the results suggest that beneficial effects of the exercise intervention may occur relatively early in time.

Although statistically significant differences in well-being indicators between conditions at certain time points indicate that exercisers felt better than controls from those time points onwards, this does not logically imply that exercisers 'felt well' in an absolute sense (i.e., demonstrate a clinical meaningful change). We found that, in 'absolute terms', exercisers felt well as regards energy and satisfaction, but not with regard to fatigue at those diverging time points. An almost satisfactory fatigue score was only reached after six weeks. Therefore, a duration of six weeks seems to be a minimally required duration for a serious exercise intervention in practice.

As to exercise experiences, psychological detachment during the exercise sessions appeared to contribute to intervention success: participants reporting high detachment did show a larger decrease in stress and fatigue, and a larger increase in energy compared to participants reporting lower detachment. Trajectories of well-being did not differ depending on exercise enjoyment variations. It should be noted that the average rate of enjoyment was high – already from the beginning of the intervention – and the amount of variance was low, leaving little variance to explain.

BOX II. Process evaluations of exercise intervention studies (Chapter 5).

- Beneficial effects of the exercise intervention became visible from two intervention weeks onwards, i.e., relatively early in time.
- In practice, a duration of six weeks seems to be a minimally required duration with a view on clinical meaningful effects.
- Students adhered quite well to the exercise sessions, but only those who were exposed to (nearly) all exercise sessions showed an increase in self-efficacy.
- Psychological detachment, i.e., the ability to switch off from study demands, appeared to be an important experience during exercise to obtain most beneficial intervention effects.

Exercise and work-related fatigue: a two-way street?

Prior work into the exercise – fatigue relationship has taken a one-way street perspective: does exercise reduce work-related fatigue? (e.g., Bernaards et al. 2006; Carson et al., 2010; Gorter, Eijkman & Hoogstraten, 2000; Jonsdottir et al. 2010; Lindwall et al., 2014; Mollart et al., 2013). However, in this thesis, it was proposed that this relationship may also be conceived as bi-directional. This is the perspective of a two-way street with exercise having an impact on fatigue, and – the other way around – with fatigue having an impact on exercise. Previous cross-sectional studies that attempted to investigate this relationship showed that employees experiencing higher levels of work-related fatigue indeed did report lower exercise levels (Ahola et al., 2012; Gorter et al., 2000). However, given the cross-sectional nature of the data collection, the direction of causality could not be inferred in these previous studies.

To provide more insight in possible bi-directional relationships between exercise and work-related fatigue, Study 3 was conducted (see Chapter 6). Study 3 is a longitudinal study with a two-wave full-panel design and a one-year time lag. This design can establish a temporal sequence and a statistical association between exercise and work-related fatigue – both of which are required for determining a true causal relation (Taris & Kompier, 2014). It was shown that the relationship between physical activity and work-related fatigue was indeed bi-directional (i.e., both 'normal' and 'reversed' causation exists): higher levels of physical activity were related to lower levels of work-related fatigue one year later, and higher levels of work-related fatigue levels were related to lower physical activity levels one year later. Although the reported effects were relatively small, these can still be compelling (see also Ford et al., 2014), especially considering the stability of our outcomes across time.

Supportive evidence for reciprocal causation corroborates the idea of a beneficial role of physical activity in reducing work-related fatigue, but also indicates that being tired from work hinders employees to engage in regular physical activity. It may even point to the risk of a potential downward spiral, in which more work-related fatigue is related to lower physical activity, which in turn relates to even higher levels of work-related fatigue. Interestingly, the sample in this study experienced on average low levels of work-related fatigue. This implies that even relatively low fatigue levels may already interfere with employees' physical activity behavior.

We also investigated employees who displayed an upward 'meaningful' change in physical activity over time (non-compliance with the physical activity norm [<5 days of at least 30 minutes physical activity] at the first time, but compliance [≥ 5 days of at least 30 minutes physical activity] at the second time) and a downward meaningful change in physical activity (compliance at the first time, and non-compliance at the second time). It was hypothesized that upward and downward physical activity changes were associated with (un)favorable changes in work-related fatigue (cf. De Lange et al., 2002; Van Hooff et al., 2005). However, no support for these hypotheses was found. This was possibly due to the dichotomization of the physical activity norm. For instance, a change from 4 to 6 days was translated as a change from non-compliance to compliance, whereas a change from 0 to 2 days was not. Since a notable proportion of participants reported just one or two days change in physical activity over time, a distinction which is based on the dichotomous physical activity norm may not have captured such slight changes in physical activity and possible accompanying effects.

Based on the rationale that work demands may deplete resources needed to engage in physical activity (e.g., Nägel and Sonnentag 2013; Kirk & Rhodes, 2011), and that physical activity may increase employees' capacity to cope with work demands, we also investigated the bi-directional relationship between work demands and physical activity in this study. Contrary to expectations, no support was found for a relationship between work demands and physical activity. Similarly, changes in compliance with the physical activity norm were not associated with (un)favorable changes in work demands. It is possible that different physical activity types (e.g., physical activity during work or leisure time) or doses (e.g., low or high intensity) are differently related to work demands. Unfortunately, due to the measurement of physical activity in this study we were not able to investigate such potential differential effects.

BOX III. Exercise and work-related fatigue: a two-way street? (Chapter 6)

- Support for reciprocal causation between physical activity and work-related fatigue was found: an increase in physical activity was related to a subsequent decrease in work-related fatigue, but also: an increase in work-related fatigue was related to a subsequent decrease in physical activity.
- Reciprocal causation points to a vicious circle in which work-related fatigue is related to lower physical activity and vice versa.
- Relatively low levels of work-related fatigue may already interfere with employees' physical activity behaviour.

Methodological considerations

Two critical issues of this thesis deserve further attention. The first issue relates to the choice for a wait list design in Study 1 and 2. The second issue relates to the measurement methods in our studies.

Non-specific intervention effects in wait list designs

A wait list design is suitable for a first evaluation of a novel intervention (Mohr et al., 2009). It implies a) a non-active control condition and b) non-blinding of participants, researchers and others involved in the study. Hence, based on this design, it cannot be excluded that non-specific factors contribute to – or even are responsible for – the reported effects. A non-specific factor is an element of the intervention that is not specified in the intervention theory, but may have resulted in improvements in intervention outcomes (Donovan, Kwekkeboom, Rosenzweig & Ward, 2009).

One might argue that such a non-specific factor in our interventions is the placebo-response. That is, exercisers may have felt better because they knew that they received a possibly effective intervention (Ekkekakis & Backhouse, 2009; Lindheimer, O'Connor & Dishman, 2015). According to this view, also controls may have felt better because of the prospect of receiving an (effective) intervention. Blinding has been proposed as a medium to diminish the chance of placebo responses (Sibbald & Roland, 1998). However, by definition, participants in our exercise trials could not be blinded since they received an active intervention. Also controls could not be blinded, since they would receive the same exercise intervention six weeks later. Researchers and trainers in the current study were not blinded as well, since this was largely impractical and even impossible. It should be noted, though, that our primary and secondary outcomes required no subjective evaluation from researchers involved in the study. This makes it very unlikely that the knowledge of researchers about group allocation may have influenced the results. Furthermore, in Study 2, we found that more of the 'pill' (i.e., exercise) led to better intervention effects. In both studies, we also found that fatigue among exercisers was still reduced at 12-week follow-up and (some) follow-up effects were stronger for those who engaged in regular exercise in this period. Together, these findings clearly point at an active ingredient of exercise itself and therefore it is not plausible that observed effects are largely due to placebo responses.

The possibility of a placebo response follows from the fact that study participants are not passive study objects (i.e., 'guinea pigs'; see Kompier & Kristensen, 2000), but rather are active unique individuals with expectations, motivations and attitudes (e.g., towards exercise or intervention effectiveness). Such expectations, motivations and attitudes are often only characterized as methodological limitations that hinder the internal validity of an intervention (Lindheimer, O'Connor & Dishman, 2015). But we would like to argue that these 'mental models' may also serve as success factors of an intervention. Participatory interventions, such as the exercise intervention in our studies, require participants who are actively involved and are motivated for exercise (Kompier & Kristensen, 2000). Future studies may employ designs that allow to identify to what extent expectations, motivations and attitudes play a role in the effect of exercise on work-related fatigue. For instance, an option is to measure participants' expectations regarding intervention effectiveness, and participants' motivation for exercise throughout the intervention period across conditions

(Ingledew & Markland, 2008; Lindheimer, O'Connor & Dishman, 2015; McCambridge, Kypri & Elbourne, 2014).

We also cannot exclude the possibility that social support or attention from researchers, group members and trainers would be non-specific intervention factors that may have contributed to intervention effects (Awa, Plaumann & Walter, 2010). The peer support of group members who are in the same condition may have contributed to participants' fatigue reductions and self-efficacy beliefs (Popp & Schneider, 2015). This latter presumption fits the social interaction hypothesis that postulates that social relationships and mutual support between those who participate in exercise activities can result in mental health improvements (Iso-Ahola & Park, 1996; Ransford, 1982). Future studies may compare individual and group exercise interventions to shed more light on this matter. They may also investigate the amount of social (peer) interaction before, during and directly after each exercise session between participants. Additionally, one might postulate that the attention of involved researchers and trainers may have resulted in a relief of fatigue (Popp & Schneider, 2015). From our data it was not possible to assess the potential contribution of the ingredient attention in our exercise intervention. However, we would like to argue that 'attention', for example feedback, technical instructions or encouragement from the trainer, is hard to disentangle from the intervention content. Future research could try to further investigate the potential contribution of this factor.

Measurement methods

In Study 1 and 2, we did not objectively measure (changes in) participants' exercise intensity during the exercise sessions (e.g., by means of heart rate monitoring), although this would have provided a better estimate of participants' exercise intensity. As a practical alternative, we instructed participants to run on an intensity that still permitted a light conversation, because prior research suggested that this is an effective tool to monitor low exercise intensity (Persinger, Foster, Gibson, Fater & Porcari, 2004). Additionally, trainers were instructed to keep an eye upon participants' running intensity, and to urge participants to lower their speed if they were short of breath and not able to talk while running. Indeed, students and employees did not rate the effort that they spent during the exercise sessions as too intensive, i.e., as respectively 6.2 and 6.5 (1 = *no effortful* at all, 10 = *extremely effortful*). We also did not use objective measures of sleep in Study 1 and 2, while it has been argued that a combination of subjective and objective sleep measures provides the most comprehensive sleep assessment (Harvey, Stinson, Whitaker, Moskovitz & Virk, 2008; Van Laethem et al., 2015). As objective measures provide additional or more detailed insight in exercise (e.g., heart rate monitors, pedometers, see Trost & O'Neill, 2013) and sleep (e.g., actigraphy, see Van de Water, Holmes & Hurley, 2011), future exercise trials may seek ways to incorporate such measures.

The measurement method of physical activity in Study 3 also deserves attention. This one-item measure was self-reported and rather global. It was based on international physical activity standards (WHO, 2010), the question being: 'on how many days a week were you physically active for at least 30 min at a moderate intensity?' Although this measure has societal relevance and provided a first understanding as to if and how physical activity and work-related fatigue are related, it was not possible to unravel the exact (i) type (e.g., non-aerobic training, physical activity as part of daily life, sport activities), (ii) frequency, (iii) duration, (iv) intensity, and (v) timing (e.g., within/outside work) of physical activity that is needed to reduce work-related fatigue. Furthermore, self-reported physical activity may well be over- or underestimated, for instance due to recall bias or social desirability (Prince et al., 2008). For future physical activity measures, I recommend the use of well-validated and detailed measures to better discern which physical activity types and doses are related to work-related fatigue (see Sylvia, Bernstein, Hubbard, Keating & Anderson, 2014 for practical recommendations). Examples of such measures may include more detailed physical activity scales (e.g., Aadahl & Jørgensen, 2003), exercise diaries (e.g., Bouchard et al., 1983) and objective measures (e.g., Hills, Mokhtar & Byrne, 2014).

Future research directions

In addition to the aforementioned methodological improvements, I believe that there are four other major suggestions for future work (see BOX IV).

Replication studies

First, I recommend replication studies with different settings or populations in order to generalize this thesis' results to a broader population. Future samples may include larger proportions of men, as women were overrepresented in Study 1 and 2. It would also be interesting to include employees experiencing clinical burnout - the 'end-stage' of work-related fatigue – to investigate whether exercise is beneficial for this population. Furthermore, fatigued employees who already engage in regular exercise may constitute an interesting sample. Research in this latter sample could be directed at how to design these employees' exercise routine in order to best reduce work-related fatigue.

Process evaluations

Second, I recommend that future exercise trials incorporate relevant process factors in their evaluation of interventions, as process evaluations are essential in accurately interpreting intervention effects (Durlak, 2015; Kompier & Aust, 2016; Kristensen, 2005; Steckler & Linnan, 2002; Nelson & Mathiowetz, 2004). In our process evaluations, we primarily focused on the 'receipt' and 'participant appraisal' of the intervention, i.e., the intervention dose (received and delivered) and participants' experiences with the intervention, since these process factors have previously been shown – and indeed proven – to be important in interpreting intervention effects (i.e., Kristensen, 2005; Moore et al., 2015; Murta, Sanderson & Oldenburg, 2007; Nielsen, Randall & Albertsen, 2007; Saunders et al., 2005; Steckler & Linnan, 2002). However, other unmeasured process factors may impact intervention effectiveness too. Therefore, I recommend future studies to include other theoretically sound process factors, such as other exercise experiences (e.g., mastery experiences, Sonnentag & Fritz, 2007), the quality of the intervention provider (e.g., practitioners may vary in their performance when implementing an intervention; Steckler & Linnan, 2002), and the context in which the intervention is conducted (e.g., the intervention may be differently implemented in a variety of settings, such as organizations or health care settings; Steckler & Linnan, 2002). Practical frameworks may help to guide these future process evaluations (e.g., see Glasgow, Vogt & Boles, 1999; Nielsen & Randall, 2013; Moore et al., 2015; Saunders, Evans & Joshi, 2005; Steckler & Linnan, 2002).

Working mechanisms

Third, further research is needed to understand the mechanisms of change underlying the pathway from exercise to work-related fatigue. This will help in theory development and in designing future effective exercise interventions (Stice, Presnell, Gau & Shaw, 2007). Both psychological (e.g., distraction hypothesis; mastery hypothesis, see Craft & Perna 2004) and physiological working mechanisms (e.g., cardiovascular fitness hypothesis, Colcombe & Kramer, 2003; monoamine hypothesis, Lin & Kuo, 2013) have as yet been put forward. However, these hypotheses have hardly been empirically tested yet, and thus need further examination before more definite conclusions can be drawn. Interestingly, this thesis showed that physical fitness increments were not essential for initial fatigue reductions, which is basically suggested by the cardiovascular fitness hypothesis (Colcombe & Kramer, 2003). Nonetheless, on the longer term, having a reasonable physical fitness level seems important to experience (daily) activities as not overly fatiguing (Åstrand, Rodahl, Dahl & Strømme, 2003; Gerber, Kellman, Hartmann & Pühse, 2010). In our studies we used physical fitness tests in which the VO_2max (i.e., indicator of physical fitness) was estimated, but future research may incorporate more direct physical fitness measures when investigating the cardiovascular fitness hypothesis, such as incremental cycle tests using gas analysis to assess oxygen uptake (Astorino et al., 2005).

This thesis may provide some suggestions for additional plausible mechanisms underlying the association between exercise and fatigue reduction. That is, the secondary outcomes included in Study 1 and 2 were chosen because there were good theoretical reasons to suggest that exercise might positively impact them. Indeed, it was shown that exercise was able to increase sleep quality and cognitive functioning in both students and employees. These two outcomes may also constitute plausible working mechanisms underlying the pathway from exercise to reduced work-related fatigue, as previous research suggests that improved sleep quality (Ekstedt, Söderström & Åkerstedt, 2009) and improved cognitive functioning may result in lower fatigue (Deligkaris, Panagopoulou, Montgomery & Masoura, 2014; Van der Linden et al., 2005). In this thesis, we were not able to demonstrate a temporal sequence in which the mediator (i.e., secondary outcome) precedes the outcome change (i.e., primary outcome), which is needed to prove mediation (Kraemer, Wilson, Fairburn & Agras, 2002). Therefore, we suggest that future research investigates whether sleep quality and cognitive functioning are indeed mediators in the exercise – fatigue relationship (see Kraemer, Wilson, Fairburn & Agras, 2002; Stice, Presnell, Gau & Shaw, 2007 for further suggestions on investigating mediation).

Exercise dose, type and timing

Fourth, further work is required on what a) dose (frequency, intensity, and duration); b) type, and c) timing (e.g., during occupational or leisure time) of exercise is best to reduce work-related fatigue. More insight in the exercise dose, type and timing may help professionals and practitioners in giving proper exercise prescriptions to fatigued individuals and may aid in designing future effective exercise interventions. The dose, type and timing of exercise in Study 1 and 2, i.e., low intensity running three times a week during leisure time, appeared to be effective in reducing fatigue. However, we do not know whether this was the optimal exercise dose, type and timing. In Study 3 it appeared that engaging in more physical activity – which includes all activities above rest level – was associated with lower work-related fatigue over time, but here as well, the exact dose, type and timing remained unknown.

As regards the dose, we suggest that future studies compare different doses (i.e., different frequencies, intensities and durations) in order to find the optimal exercise dose for reducing work-related fatigue. It seems reasonable that the exercise dose in such studies should not be too high, as this may not or even negatively affect fatigue (Brooks & Carter, 2013), especially in participants who are already fatigued at the start.

With respect to exercise type, different exercise types can be compared in order to find out which type reduces work-related fatigue (best). In our interventions running was chosen since it is easy to implement: only running shoes are needed and running is highly flexible in terms of time and place. It was also appreciated by participants (see Chapter 4 and 5). Unfortunately, running also brings a relatively high risk of injuries (Van Mechelen, 1992), as was also evidenced in Chapter 4. Therefore, aerobic exercise types that – compared to running – are less prone to injuries than running (e.g., cycling, brisk walking) could also be considered. Additionally, there are indications that also anaerobic exercise (e.g., strength training, yoga) may reduce work-related fatigue (Bretland & Thorsteinsson, 2015), and is thus worthy of consideration.

The timing of exercise constitutes another important research topic. One may distinguish between physical activity during leisure time and work time. Physical activity could be work-related (Caspersen, Powell & Christenson, 1985), which often bears the risk of unhealthy activities and musculoskeletal problems (Holtermann et al., 2012). Physical activity (e.g., exercise) may have a greater potential in reducing work-related fatigue if it is an isolated activity with a specific purpose and pursued during leisure time. One may assume that in this case fatigued individuals will find a better opportunity to detach from work and to obtain mastery experiences (Demerouti et al., 2009; Geurts & Sonnentag, 2006; Sonnentag & Jelden, 2009).

BOX IV. Recommendations for future research.

- Replication studies (i.e., exercise trials, longitudinal studies) using different samples and settings, e.g., employees with clinical burnout.
- Investigation of the mechanisms of change underlying the pathway from exercise to work-related fatigue, e.g., psychological and physiological working mechanisms.
- Process evaluations in future exercise trials. Process factors should at least include dose delivered, dose received and fidelity. Other theoretically sound process factors may also be considered.
- Investigation of the best dose, type and timing of exercise to reduce work-related fatigue.

Practical recommendations

Based on the findings of this thesis, several practical recommendations can be formulated for individuals (see BOX V), organizations (see BOX VI), health care and policy (see BOX VII).

Employees and students

At an individual level, I encourage inactive fatigued students and employees to take up regular exercise. Our studies consistently showed that exercise reduces study- and work-related fatigue. Fatigued students and employees may also benefit from exercise in terms of improved sleep, better cognitive functioning and work ability.

I advise fatigued employees and students to slowly increase their exercise level. I suggest to start with regular low-intensity exercise. Low intensity implies that upholding a light conversation is still possible during exercise (Persinger, Foster, Gibson, Fater & Porcari, 2004). One rest day (i.e., no exercise) may be considered between exercise days to allow for (bodily) recovery from exercise and to prevent the building up of fatigue levels. This also helps to reduce the risk of injuries (McKelvie, Valliant & Asu, 1985). The graded running protocol that we used in the intervention studies provides an example for slowly building up regular exercise (see Appendix C). At least, I advise against overdoing exercise (e.g., too high intensity, duration and frequency) in combination with insufficient (bodily) recovery, since this may increase fatigue or even contribute to burnout (Graaf-Roelfsema, Keizer, Van Breda, Wijnberg & Van der Kolk, 2007; Gustafsson, 2007).

As it appeared that psychological detachment during exercise was shown to maximize fatigue reductions (see Chapter 5), I also recommend to arrange exercise sessions in a way that fosters 'switching off' from work or study demands (Sonnentag & Fritz, 2015). For instance, one may not be allowed to bring a (work) smartphone along while exercising in order to prevent that, for example, signals from incoming messages or calls direct attention to possible work or study hassles (Derks, van Mierlo & Schmitz, 2014). Exercise may also be carried out in an environment that advances cognitive distraction, for example in nature (outside, wood; e.g., Barton & Pretty, 2010).

I also recommend fatigued individuals to choose an exercise type that they find enjoyable, because research shows that this is important for continued participation in exercise (Ekkekakis, Parfitt & Petruzzello, 2011; Hagberg, Lindahl, Nyberg, & Hellénius, 2009). For (fatigued) students and employees who already engage in regular exercise, it seems advisable to build or strengthen an 'exercise habit', without overdoing it. Chapter 6 of this thesis and other prior work (e.g., Bernaards et al., 2006; Eriksen & Bruusgaard, 2004) suggest that regular exercise may help to prevent the (further) development of work-related fatigue for this group as well.

BOX V. Practical recommendations for employees and students experiencing study- and work-related fatigue.

- Build up your exercise level gradually (see Appendix C for a graded running protocol). Start with regular low-intensity exercise. This means that upholding a light conversation is still possible during exercise. Consider one rest day (i.e., no exercise) between exercise days to allow for sufficient (bodily) recovery.
- Arrange exercise in a way that fosters 'switching off' from work or study demands. For instance do not bring your smart phone during exercise or choose an exercise environment that fosters cognitive distraction.
- Choose an exercise type that you find enjoyable.
- For employees with work-related fatigue and students with study-related fatigue who already engage in regular exercise: keep up with this routine without overdoing it (i.e., avoid exercise of too high intensity, frequency and duration, and ensure sufficient recovery between exercise sessions) and strengthen an 'exercise habit'.

Employers and higher education institutions

At an organizational level, it is recommended that employers invest in primary prevention (Kompier & Kristensen, 2000; Tetrick & Quick, 2003). Primary prevention aims to prevent illness before it even occurs. Also from a legal perspective, employers have a duty to invest in primary prevention in order "to ensure the safety and health of workers in every aspect related to work" (Widerszal-Bazyl, Zolnierczyk-Zreda & Jain, 2008, p.38). This duty also applies to problems of work-related stress in so far they entail a risk for negative (mental) health effects such as work-related fatigue (De Lange et al., 2003). Primary prevention may be directed at the work situation or at the individual (Kompier & Kristensen, 2000). As regards the first, employers should, for instance, ensure that employees' work demands are challenging but not too high in order to prevent work-related fatigue (Maslach, Schaufeli & Leiter, 2001). As regular exercise may reduce the risk of developing work-related fatigue (Bernaards et al., 2006; Eriksen & Bruusgaard, 2004; Mammen & Faulkner, 2013), the stimulation of exercise by employers constitutes a type of individual-directed primary prevention. For example, employers could stimulate physically active transportation to work (Loong, Van Lierop & El-Geneidy, 2017; Saunders, Green, Petticrew, Steinback & Roberts, 2013), design 'active' workplaces (Commissaris et al., 2016) and provide sport facilities at work (Halonen et al., 2015). It may even be cost-effective for employers to provide the opportunity for employees to exercise during paid work time (see Coulson, McKenna & Field, 2008; Thiele Schwarz & Hasson, 2012).

Secondary prevention aims to reduce the impact of illness that has already occurred. It involves reducing the severity of the symptoms before they lead to more serious problems (Kompier & Kristensen, 2000; Tetrick & Quick, 2003). Secondary prevention may also be directed at the work situation or the individual. Exercise may especially fit the individual-directed secondary prevention approach. We recommend employers to provide fatigued employees (who are thus 'at-risk' for more serious burnout symptoms) the possibility to take part in an exercise program. Such a program may not only result in fatigue reductions, but also serve as prevention for the development of more severe problems such as clinical burnout (Roelofs, Verbraak, Keijsers, De Bruin & Schmidt, 2005).

Comparable recommendations as regards primary and secondary prevention may apply to higher education organizations, such as universities. For instance, such organizations should ensure that study load for students is not too high. For example by systematically checking whether the study load for a particular course fits the number of study credit points, i.e., whether this load is realistic. Additionally, higher education institutions may encourage students to make use of sport facilities (Plotnikoff et al., 2015), even more so since the transition from secondary to tertiary education for students often results in a decline in exercise levels (Buckworth & Nigg, 2004). With respect to secondary prevention, counselling services within higher education institutions may provide exercise programs for those students who show early signs of burnout (i.e., study-related fatigue). The exercise intervention that is presented in Chapter 2 seems to be a simple, accessible and effective intervention to target these early burnout symptoms.

BOX VI. Practical recommendations for employers and higher education institutions.

Employers

- Invest in work- and individual directed primary prevention that is aimed at preventing the development of work-related fatigue.
- Include exercise in individual-directed primary prevention strategies. Examples of such initiatives include the stimulation of physically active transportation to work, the design of active workplaces and the provision of sport facilities at work.
- Provide fatigued employees (who thus are 'at-risk' for developing burnout) the possibility to take part in an exercise program (secondary prevention).

Higher education institutions

- Invest in primary prevention (e.g., a feasible study curriculum) that is aimed at preventing the development of study-related fatigue.
- Stimulate students to exercise, for instance by encouraging them to make use of (university) sport facilities.
- Provide fatigued students who show early signs of burnout (i.e., study-related fatigue) an exercise program (secondary prevention), such as the exercise program employed in the current thesis (see Appendix C).

Policy and health care

At the level of policy and health care, results of this thesis may be especially valuable for professionals who develop interventions. We found that a relatively short intervention of six weeks is effective to observe meaningful changes in fatigue and other indicators of student and employee well-being. This finding implies that in order to bring about improvements in well-being, exercise interventions do not need by definition to be very long. This information is relevant, since the duration may affect intervention features such as costs and staffing. In fact, this thesis showed that beneficial effects on well-being may become visible from two intervention weeks onwards. As clinical meaningful changes were first observed after six weeks of exercise, a duration of six weeks seems to be a minimal recommendation for exercise intervention duration in practice. After intervention completion, it seems important that participants maintain regular exercise and form an 'exercise habit'. Therefore, I suggest that professionals also stimulate participants' exercise behaviour after the intervention has ended, for example, along the tradition of motivational counseling (Bock, Marcus, Pinto & Forsyth, 2001).

Furthermore, as intervention compliance proved to be a prerequisite for obtaining (most) beneficial effects, it is important to offer the exercise intervention in a way that it is feasible for participants to adhere to. We found that fatigued employees are willing to engage in the exercise intervention, but that time constraints often limited them to do so (see Chapter 4). Tailoring the exercise intervention to participants' practical possibilities, e.g., by offering the exercise sessions at several times a week, is therefore recommended. Additionally, to increase compliance, one might consider to adjust the exercise type to the capacity of the participant. Given that some employees (see Chapter 4) dropped out during the intervention because of running injuries, less demanding exercise activities can also be considered. However, as running was effective and was also appreciated by students and employees (see Chapter 4 and 5), running is still in place.

Additionally, as individuals with high levels of fatigue may first enter primary care (i.e., health care that people initially contact when they seek help for their health problems), this thesis' results may also be valuable for these professionals. General practitioners and occupational physicians may prescribe exercise (programs) for individuals who are fatigued as a result from work or study stress. Additionally, physiotherapists may consider offering an exercise program like the exercise intervention in this thesis. In an ideal situation, general practitioners or occupational physicians may refer fatigued individuals to professionals who can deliver exercise interventions aimed at reducing study- or work-related fatigue. For instance, in some countries (e.g., The Netherlands, Belgium and Germany) running therapists do exist. These are professionals especially trained in supervising exercise for people with mental health problems such as study- and work-related fatigue or burnout.

In primary care, exercise fits into a 'stepped care' approach for the treatment of burnout. This means that care is offered not earlier or more intensely than necessary and not later or less intensely than needed (Seekles, Van Straten, Beekman, Van Marwijk & Cuijpers, 2011). Because exercise is an effective means for the reduction of study- or work-related fatigue, and because it is not associated with adverse side-effects, exercise may be included in guidelines as one of the options that should be (first) offered to people who show early signs of burnout. Progress of exercise effectiveness should be monitored. This means that in case of non-response to the exercise, people may 'step up' to another treatment form (Seekles, Van Straten, Beekman, Van Marwijk & Cuijpers, 2011).

BOX VII. Practical recommendations for policy and healthcare.

Professionals who develop interventions

- Exercise interventions aimed at reducing study- or work-related fatigue do not need to be very long. A duration of six weeks seems to be a minimal recommendation for exercise intervention duration in practice.
- Offer the exercise intervention in a way that it is feasible for participants to adhere to, and in a way that stimulates exercise on the longer term.

Healthcare professionals

- Prescribe or deliver exercise (programs) for those experiencing study- or work-related fatigue.
- Refer to professionals who can deliver an exercise intervention aimed at reducing study- or work-related fatigue.
- Exercise can be one of the options that should be (first) offered to people who show early signs of burnout (i.e., study- or work-related fatigue). As such, exercise fits a 'stepped care' approach for burnout.

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APPENDICES

APPENDICES A-C

Appendix A: Supplementary material Chapter 4

Supplementary file I. *Per protocol analysis: Means and standard deviations pre (T0) and post (T1) intervention for participants in the EI (n = 31) and WLC (n = 35) group of emotional exhaustion, overall fatigue, need for recovery, sleep quality, sleep quantity, general self-efficacy, work self-efficacy and work ability.*

Outcome (theoretical range)	Group	T0		T1			Intervention effects[b]	
		M	*SD*	*M*	*SD*	*d*[a]	*F*	η^2
Emotional Exhaustion (0-6)	EI	3.17	0.81	2.44	1.25	-0.69	**4.42***	**.07**
	WLC	3.58	1.04	3.24	1.31	-0.29		
Overall Fatigue (10-50)	EI	27.16	3.95	24.03	5.63	-0.64	**4.33***	**.06**
	WLC	30.43	6.45	29.14	7.10	-0.19		
Need for Recovery (1-4)	EI	2.45	0.61	2.27	0.62	-0.29	2.78	.04
	WLC	2.84	0.69	2.87	0.98	0.04		
General self-efficacy (1-5)	EI	3.73	0.41	3.78	0.39	0.13	0.93	.01
	WLC	3.48	0.52	3.46	0.63	-0.04		
Work self-efficacy (0-6)	EI	3.97	1.02	4.15	0.95	0.18	0.54	.01
	WLC	3.84	0.98	3.98	1.05	0.14		
Sleep Quality (0-6)	EI	3.75	1.57	3.00	1.81	-0.44	**5.54***	**.08**
	WLC	3.60	1.31	3.71	1.47	0.08		
Sleep Quantity	EI	7.07	0.93	7.13	0.95	0.06	0.37	.01
	WLC	6.99	0.95	6.98	0.94	-0.01		
Work ability	EI	7.89	1.11	8.00	1.16	0.10	**4.58***	**.07**
	WLC	7.36	1.95	6.89	2.18	-0.23		

[a] Within-group Cohen's d

[b] Pre- and post-comparisons: ANCOVA with the post-intervention score (T1) as dependent variable and the baseline score (T0) as covariate.

* p < .05, ** p < .01

Supplementary file II. *Per protocol analysis: means and standard deviations of indicators of cognitive functioning pre (T0) and post (T1) intervention.*

Outcome (theoretical range) [cognitive task]	Group	T0		T1			Intervention effects[d]	
		M	*SD*	*M*	*SD*	*d*[a]	*F*	η^2
Self-reported cognitive functioning (0-100)	EI	39.97	12.76	37.23	9.16	-0.25	**6.67***	**.10**
	WLC	44.14	11.74	44.89	12.84	0.06		
Updating [N-back][b]	EI	59.03	16.42	66.93	19.16	0.44	.02	<.01
	WLC	57.02	22.72	65.14	17.36	0.40		
Inhibition [SART][b]	EI	30.48	7.30	32.48	8.79	0.25	0.74	.01
	WLC	33.86	8.24	32.90	8.83	-0.11		
Switching [Matching Task][c]	EI	133.95	172.35	107.18	115.26	-0.18	0.19	<.01
	WLC	103.46	127.15	88.88	134.30	-0.11		
Subjective costs (1-10)								
Fatigue (before)	EI	5.84	1.67	4.73	1.96	-0.61	**7.05***	**.11**
	WLC	5.37	2.10	6.00	1.84	0.32		
Fatigue (after)	EI	6.50	1.87	5.60	2.08	-0.46	1.45	.03
	WLC	6.59	1.86	6.24	1.94	-0.18		
ΔFatigue[e]	EI	0.78	1.88	0.87	1.59	0.05	1.28	.02
	WLC	1.09	1.09	0.31	1.77	-0.43		
Motivation	EI	8.83	1.18	8.73	0.83	-0.10	1.06	.02
	WLC	9.13	0.86	8.60	1.00	-0.56		
Demands	EI	7.29	1.26	6.32	1.46	-0.71	**5.21***	**.08**
	WLC	7.77	1.00	7.41	1.51	-0.28		
Effort	EI	8.73	0.91	8.83	0.87	0.11	0.78	.01
	WLC	8.76	1.02	8.62	1.24	-0.12		

[a] Within-group Cohen's d
[b] Number of correct responses
[c] Switch cost in milliseconds
[d] Pre- and post-comparisons: ANCOVA with the post-intervention score (T1) as dependent variable and the baseline score (T0) as covariate.
[e] Difference in fatigue before and after the cognitive test battery
* $p < .05$, ** $p < .01$

Supplementary file III. *Per protocol analysis: means and standard deviations of indicators of aerobic fitness pre (T0) and post (T1) intervention.*

Outcome (theoretical range)	Group	T0		T1			Intervention effects[b]	
		M	*SD*	*M*	*SD*	*d*[a]	*F*	η^2
Aerobic fitness (VO_2max)	EI	31.60	4.40	33.53	5.05	0.41	.02	<.01
	WLC	27.60	5.40	29.86	5.98	0.40		
Subjective costs (1-10)								
Fatigue (before)	EI	5.86	1.83	4.66	2.00	-0.63	**7.55****	**.12**
	WLC	6.39	1.89	6.21	1.91	-0.10		
Fatigue (after)	EI	4.72	1.58	3.62	1.90	-0.63	**6.45***	**.11**
	WLC	5.71	1.74	5.32	1.91	-0.21		
ΔFatigue[c]	EI	-1.14	1.96	-1.03	1.88	-0.06	0.01	<.01
	WLC	-0.68	1.52	-0.89	2.38	0.11		
Motivation	EI	8.93	0.84	9.03	0.78	0.12	2.33	.04
	WLC	8.50	1.45	8.50	1.17	<.01		
Demands	EI	4.59	2.04	4.00	1.79	-0.31	**5.34***	**.09**
	WLC	5.00	2.02	5.25	2.08	0.12		
Short of breath	EI	3.52	2.01	3.10	1.76	-0.22	0.67	.01
	WLC	4.14	2.05	3.79	2.08	-0.17		
Effort	EI	9.17	0.76	8.93	0.88	-0.29	1.00	.02
	WLC	8.79	1.07	8.96	0.92	0.17		

[a] Within-group Cohen's d

[b] Pre- and post-comparisons: ANCOVA with the post-intervention score (T1) as dependent variable and the baseline score (T0) as covariate.

[c] Difference in fatigue before and after the aerobic fitness test

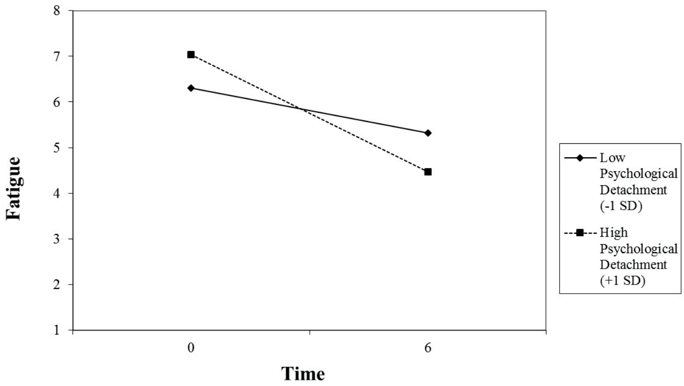
* $p < .05$, ** $p < .01$

Appendix B: Supplementary material of Chapter 5

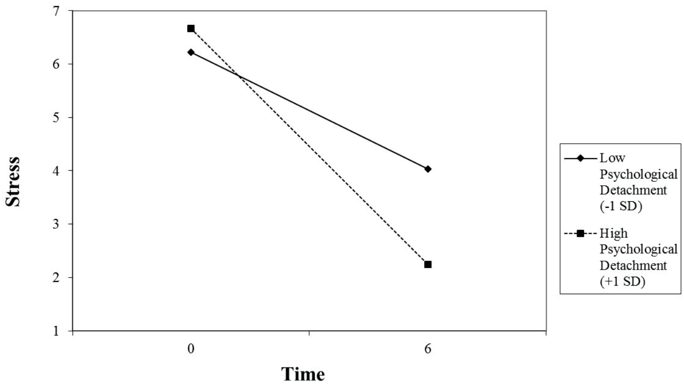
Supplementary file I. *Correlations between study variables.*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.[a]	12.[a]	13.[a]
1.Gender		.15**	-.20***	.12**	.06	-.09*	-.12**	.06	.00	-.05	-.09	.00	-.01
2.Age	-.15		.05	-.22***	-.08*	.03	-.10*	-.09*	-.03	-.05	-.13*	.00	.13*
3.Weekly study hours	.20*	.05		-.13***	-.04*	.10**	-.02	-.02	.12**	-.02	.08	-.04	-.08
4. Exam period	.13	.20	.10		.02	-.04	-.01	-.02	.06	.05	.05	-.18**	-.11
5.Health status	-.05	-.15	-.07	.02		-.28***	.44***	.55***	-.11**	.34***	.24***	.25***	.00
6.Fatigue	.14	.03	.21*	.06	-.23*		-.24***	-.46***	.48***	-.18***	-.09	.07	-.06
7. Satisfaction	.20	-.12	-.05	.05	.53***	-.03		.58***	-.28***	.55***	.15**	.27***	.04
8. Energy level	-.09	-.13	-.02	.09	.63***	-.27***	.64***		-.19***	.41***	.28***	.26***	.01
9. Stress level	-.01	-.06	.21*	-.12	-.12	.67***	-.16	-.09		-.21***	.04	-.01	-.31***
10. Self-efficacy	.08	-.09	-.02	-.05	-.14	-.14	.63***	.51***	-.10		.15*	.15*	-.02
11. Exposure[a]	.17	-.22	.11	-.07	-.09	-.09	.19	.31*	-.02	.22		.19**	-.05
12. Enjoyment[a]	.11	-.24	.05	.23	.08	.08	.42**	.44**	.03	.30*	.47**		.28***
13. Detachment[a]	.01	.23	-.15	.10	.02	.02	-.117	-.24	-.28	.17	-.18	.06	

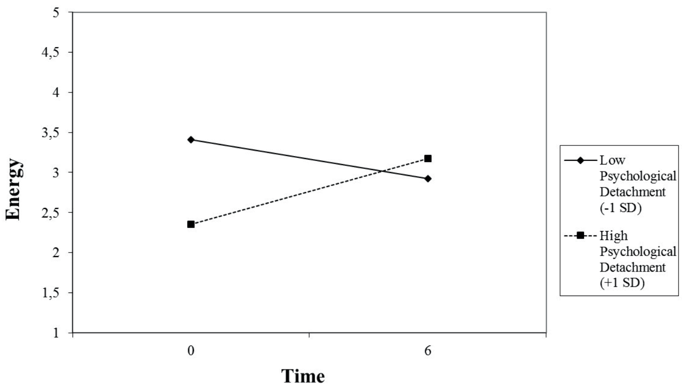
[a] Only correlations for participants in the exercise condition.
Below diagonal: Between persons ($n = 99$); Above diagonal: Within persons ($n = 693$);
* $p < .05$, ** $p < .01$, *** $p < .001$ (two-tailed)



Supplementary file II. *Psychological detachment moderates the trajectory of fatigue.*



Supplementary file III. *Psychological detachment moderates the trajectory of stress.*



Supplementary file IV. *Psychological detachment moderates the trajectory of energy.*

B

Appendix C: Graded running protocol

Week	Training 1[a]	Training 2[a]	Training 3[a]
1	10*1 minute, rest between intervals[b]: 2 min.	6*2 min., rest: 2 min.	1-2-1-2-1-2-1 min., rest: 2 min.
Total time of the training (incl. rest)	*30 min.*	*24 min.*	*22 min.*
2	3*3 min., 2*2 min., 2*1 minute., rest between intervals: 1 minute; rest between sets: 2 min.	7*2 min., rest between intervals: 2 min.	3* (1-2-3), rest between intervals: 1 minute; rest between sets: 2 min.
Total time of the training (incl. rest)	*22 min.*	*28 min.*	*24 min.*
3	1-2-3-4-3-2-1 min., rest between intervals: 1 minute.	5*3 min., rest between intervals: 2 min.	1-3-1-3-1-3-1, rest between intervals: 2 min.
Total time of the training (incl. rest)	*23 min.*	*25 min.*	*23 min.*
4	1-2, 1-3, 1-4, 1-5 min., rest between intervals: 1 minute; rest between sets: 2 min.	5*4 min., rest between intervals: 2 min.	2*6 min., rest between intervals: 3 min. + 2*4 min., rest between intervals: 3 min.
Total time of the training (incl. rest)	*28 min.*	*30 min.*	*26 min.*
5	2* (6-4-2) min., rest between intervals: 1 minute; rest between sets: 3 min.	2*8 min., rest between intervals: 4 min.	5*5 min., rest between intervals: 2 min.
Total time of the training (incl. rest)	*29 min.*	*20 min.*	*35 min.*
6	2-4-6-8-6-4-2, rest between intervals: 1 minute	2*10 min., rest between intervals: 3 min.	20 min. uninterrupted running
Total time of the training (incl. rest)	*32 min.*	*20 min.*	*23 min.*

Note. [a] Include 10 minutes (brisk) walking as a warm-up and cooling-down. Running should be conducted at a low intensity. This means that having a light conversation is still possible. [b] Rest = (Brisk) walking; Min. = minutes.

SUMMARY

Summary

Work-related fatigue and burnout

Many employees show high levels of fatigue (estimated at 18% in Europe). Fatigue can be described as a subjective feeling of having a reduced capacity to complete mental or physical activities. Fatigue among employees often results from prolonged work stress, and thus can be regarded as 'work-related'. It can best be understood as a continuum, ranging from acute fatigue that occurs after a work day and disappears after a relatively short rest period, to a severe and persistent form of fatigue that occurs after a long period of (work) stress. 'Burnout' reflects the end-stage of this continuum, in which the employee is often not able to work anymore. In the current thesis, we used the term 'work-related fatigue' or simply 'high levels of fatigue'. Doing so, we point to serious persistent fatigue that can be attributed to prolonged stress in the work context.

Work-related fatigue is associated with substantial losses in employees' health and well-being, such as decreased cognitive functioning and a higher risk for developing cardiovascular diseases. Employers face consequences such as lost productivity time and presenteeism. Estimations of annual costs to society caused by work-related fatigue vary from 136.4 billion dollar (figures related to the U.S.) to 200 billion euro (figures related to Europe). Given the high prevalence of work-related fatigue and its negative consequences for employees, employers and society, it is valuable to examine potential approaches to reduce it.

Exercise and work-related fatigue

Exercise may constitute an effective approach to reduce work-related fatigue. Assets of exercise for the reduction of fatigue include its accessibility, low costs, and positive 'side effects', such as reduced risk for cardiovascular diseases. Various pathways have been proposed to explain the relationship between exercise and work-related fatigue, yet the underlying mechanisms are still uncertain. Probably, a combination of psychological (e.g., psychological detachment) and physiological mechanisms (e.g., cardiovascular fitness hypothesis) is responsible for the positive effects of exercise on fatigue.

Although previous empirical studies support the notion that exercise may reduce work-related fatigue, causal inferences could not be drawn. This was because knowledge about this relationship was largely based on correlational studies, and the relatively few available intervention studies lacked methodological quality and process evaluations. Moreover, earlier studies ignored the possibility that individuals' fatigue may also influence the amount of exercise they engage in.

Aim of this thesis

Against this background, the main purpose of this thesis was to advance knowledge about the extent to which exercise is effective in reducing work-related fatigue. To this purpose, three related empirical studies with strong methodological designs were carried out. These studies enabled us to overcome key limitations of previous studies: i) lack of well-designed exercise intervention studies aimed at reducing work-related fatigue; ii) lack of process evaluations in exercise intervention studies aimed at reducing work-related fatigue; and iii) lack of knowledge of potential bi-directional relations between exercise and work-related fatigue. Results of these three studies are considered against the background of these limitations.

Effect evaluation of exercise intervention studies aimed at reducing work-related fatigue

Two randomized controlled trial (RCT) studies were conducted to address the first limitation (i.e., lack of well-designed exercise intervention studies aimed at reducing work-related fatigue). The RCT design acknowledges randomization, control condition(s), and longitudinal data collection, and therefore better allows for causal inferences. In both studies, we investigated individuals with high levels of fatigue. They were randomly assigned to either an exercise intervention or a wait list control condition. This made it possible to test the effect of exercise on work-related fatigue compared to the 'natural course' of fatigue. The exercise intervention included supervised (two one-hour sessions a week) and unsupervised (one one-hour session a week) low-intensity running, for six consecutive weeks.

The effect evaluation of *Study 1* is reported in **Chapter 2**. Participants were students with study-related fatigue who were still able to study. Study-related fatigue refers to fatigue resulting from prolonged study stress, and therefore largely resembles work-related fatigue. Exercise was found to have a small-to-moderate effect on reducing study-related fatigue. In *Study 2* (see **Chapter 3**: study protocol, and **Chapter 4**: effect evaluation) participants were employees with work-related fatigue who were still able to work. When all participants were included in the analysis, exercise did not reduce work-related fatigue. However, a closer examination of participants' compliance revealed that 29% of exercisers did not start exercising or gave up exercising before the end of the intervention, and 21% of the controls did not wait but increased their exercise level during the intervention period. A comparison between 'true' exercisers and 'true' controls revealed that exercise had a moderate effect on reducing work-related fatigue. This result implies that the exercise intervention works for those employees who adhere to the intervention.

In our studies, exercise also resulted in beneficial changes in other outcomes. Consistent across students and employees, we found improvements in sleep quality, (self-reported) cognitive functioning, work ability (which was only measured among employees), and less self-reported demands during cognitive tests. No effects were found for self-efficacy, sleep duration, (most) 'objective' indicators of cognitive functioning and objectively measured physical fitness. It is possible that a different exercise 'dose' is needed to observe differences in these latter outcomes. In both studies, initial intervention effects were maintained on the longer term, i.e., until 12 weeks after the intervention. Small further improvements were found in study- and work-related fatigue at follow-up, and in physical fitness (students) and need for recovery (employees) for those who continued exercising during follow-up.

Process evaluation of exercise interventions

Effect evaluation of intervention studies, i.e., a comparison of pre- and post-intervention outcomes, allows for an understanding of 'what works', but does not provide insight as to 'when, how and why' this may be the case. Process evaluation opens the 'black box' to see what happened during the intervention period. It explores the implementation (i.e., the way a program is put into practice), receipt (i.e., dose and views of participants) and setting (i.e., general intervention and implementation context) of the intervention and helps in interpreting intervention outcomes. Previous studies lacked such valuable process evaluations.

To address this second limitation (i.e., lack of process evaluations in exercise intervention studies aimed at reducing work-related fatigue), we aimed to open the 'black box' of the intervention period of *Study 1* and *Study 2*[1]. To this end, participants were measured before, five times during and immediately after the six-week intervention period on well-being indicators and process factors. In *Study 1* (see **Chapter 5**), six indicators of well-being among both exercisers and controls ('fatigue', 'energy', 'stress', 'health', 'satisfaction' and 'self-efficacy') were measured. Process variables were only measured among exercisers and included exposure (i.e., 'dose received') and participants' experiences of the intervention (i.e., enjoyment and psychological detachment). We examined i) whether actual exposure to the exercise sessions was related to differences in participants' trajectories of well-being, ii) the minimally required exposure to exercise needed before well-being started to differ between the intervention and control condition, and iii) whether exercise experiences (enjoyment and detachment) were related to differences in well-being trajectories.

As to 'exposure', all participants adhered quite well to the exercise sessions, but only those who were exposed to (nearly) all exercise sessions showed an increase in self-efficacy. Possibly, the overall high exposure rate and the low variance in exposure may have played a role in the absence of significant findings with regard to the other well-being indicators.
With respect to the minimally required exposure, it was found that student-exercisers displayed lower fatigue than controls, from two intervention weeks onwards. For energy and satisfaction, beneficial effects of exercise became visible from around the fourth week.

1 Results of the process evaluation of employees are not part of this thesis (manuscript in preparation)

Together, these results suggest that beneficial effects of the exercise intervention may occur relatively early in time. These early effects reflected statistical differences between exercisers and controls, but may not reflect clinical meaningful effects. A duration of six weeks seems to be a minimally required duration with a view on clinical meaningful effects.

As to exercise experiences, psychological detachment during the exercise sessions, i.e., the ability to switch off from study demands, appeared to contribute to intervention success: participants reporting high detachment showed a larger decrease in stress and fatigue, and a larger increase in energy compared to participants reporting lower detachment. Trajectories of well-being did not differ depending on exercise enjoyment variations. It should be noted that the average rate of enjoyment was high – already from the beginning of the intervention – and the amount of variance was low, leaving little variance to be explained.

Exercise and work-related fatigue: a two-way street?

Prior work into the exercise – fatigue relationship had taken a one-way street perspective: does exercise reduce work-related fatigue? This relationship may also be conceived as bi-directional, though. This is the perspective of a two-way street with exercise having an impact on fatigue, and – the other way around – with fatigue having an impact on exercise. Previous studies that investigated this relationship showed that employees experiencing higher levels of work-related fatigue indeed reported lower exercise levels. However, given the cross-sectional nature of the data collection in these previous studies, the direction of causality could not be inferred.

Against this background, we conducted *Study 3*, a longitudinal study with a two-wave full-panel design and a one-year time lag (see **Chapter 6**). This design can establish a temporal sequence and a statistical association between exercise and work-related fatigue – both of which are required for determining a true causal relation. Support was found for a bi-directional relationship (i.e., both 'normal' and 'reversed' causation exist): higher levels of physical activity were related to lower levels of work-related fatigue one year later, and higher levels of work-related fatigue levels were related to lower physical activity levels one year later. This result corroborates the idea of a beneficial role of physical activity in reducing work-related fatigue, but also indicates that being tired from work hinders employees to engage in regular physical activity. It may point to a vicious circle in which work-related fatigue is related to lower physical activity and vice versa.

The effects of across-time change in meaningful physical activity groups on levels of employees' work-related fatigue were also studied. These groups were based on employees' compliance with the international physical activity norm (i.e., ≥ 5 days 30 minutes moderate intensity physical activity). Employees whose compliance with this norm changed over one year showed fairly stable levels of work-related fatigue over time. Possibly, the dichotomization of the physical activity norm made it impossible to capture slight physical activity changes and possible accompanying changes in fatigue.

Methodological considerations of this thesis

Two issues of this thesis deserve further attention. First, we used a wait list design in *Study 1* and *2*. A wait list design is suitable for a first evaluation of a novel intervention. However, based on such a design, it cannot be excluded that non-specific factors contribute to – or even are responsible for – the reported effects. A non-specific factor is an element of the intervention that is not specified in the intervention theory, but may have resulted in improvements in intervention outcomes. Non-specific effects in our studies might include placebo-responses (i.e., participants' expectations about the effectiveness of the intervention), social support and attention from researchers, peers and trainers. However, given that follow-up effects were found and more exercise was related to stronger intervention effects, it is not plausible that effects are largely due to these non-specific effects. Future research could try to further investigate the potential contribution of these non-specific factors.

Second, the measurement methods of exercise and sleep in our studies deserve attention. In *Study 1* and *2*, we did not objectively measure (changes in) participants' exercise intensity during the exercise sessions (e.g., heart rate monitoring), although this would have provided a better estimate of participants' exercise intensity. Similarly, sleep was not assessed objectively, while such an assessment would have given more detailed insight in sleep (e.g., actigraphy). Furthermore, in *Study 3*, we used a one-item self-reported physical activity measure, which may have led to an over- or underestimation of participants' actual physical activity level. Based on this measure, we could also not unravel the exact type, frequency, duration, intensity and timing (e.g., within/outside work) of physical activity that is needed to reduce work-related fatigue. Future exercise trials may seek ways to incorporate well-validated and detailed objective or self-reported measures to measure exercise and sleep more precisely.

Future research directions

Four major research directions in future studies can be formulated. First, I recommend replication studies with different settings or populations in order to generalize this thesis' results to a broader population, such as employees experiencing clinical burnout - the 'end-stage' of work-related fatigue – or employees who already engage in regular exercise.

Second, I recommend that future exercise trials incorporate relevant process factors in their evaluation of interventions, as process evaluations are essential in accurately interpreting intervention effects. I advise to include theoretically sound process factors and to use practical frameworks to guide these process evaluations.

Third, further research is needed to understand the mechanisms of change underlying the pathway from exercise to work-related fatigue. This will help in theory development and in designing future effective exercise interventions. I suggest to investigate both psychological (e.g., distraction hypothesis; mastery hypothesis) and physiological (e.g., cardiovascular fitness hypothesis) working mechanisms that already have been put forward in the literature. This thesis may lead to the investigation of sleep and cognitive functioning as two additional plausible working mechanisms.

Fourth, further work is required on what a) dose (frequency, intensity, and duration); b) type, and c) timing (e.g., during occupational or leisure time) of exercise is best to reduce work-related fatigue. More insight in the exercise dose, type and timing may help professionals and practitioners in giving proper exercise prescriptions to fatigued individuals and may aid in designing future effective exercise interventions.

Practical recommendations

Based on this thesis, practical recommendations can be formulated for individuals, organizations, health care and policy. At an individual level, I encourage fatigued students and employees to take up regular exercise. I suggest to start with regular low-intensity exercise. Low intensity implies that upholding a light conversation is still possible during exercise. The graded running protocol that we used in the intervention studies provides an example for taking up regular exercise (see Appendix C). I also recommend to arrange exercise sessions in a way that fosters 'switching off' from work or study demands, for instance by carrying out exercise in nature. Choosing an exercise type that one enjoys may help in continuing exercise on the longer term. For (fatigued) students and employees who already engage in regular exercise, it seems advisable to build or strengthen an 'exercise habit', without overdoing it.

At an organizational level, it is recommended that employers invest in primary prevention and secondary prevention. Primary prevention is aimed to prevent illness before it even occurs. Secondary prevention aims to reduce the impact of illness that has already occurred, before it leads to more serious problems. Both prevention strategies may be directed at the work situation or at the individual. As to work-directed primary prevention, employers should, for instance, ensure that employees' work demands are challenging but not too high to prevent work-related fatigue. Exercise fits the individual prevention approaches. As regards primary prevention, employers could stimulate exercise to diminish the risk of developing work-related fatigue, for instance by providing sport facilities at work. As regards secondary prevention, employers may provide fatigued employees (who are thus 'at-risk' for more serious burnout symptoms) the possibility to take part in an exercise program.

Comparable recommendations as regards primary and secondary prevention apply to higher education organizations, such as universities. Organizations should ensure that study load for students is not too high, and encourage students to make use of sport facilities. Counselling services within higher education institutions may provide exercise programs for those students who show early signs of burnout (i.e., study-related fatigue).

At the level of policy and health care, results of this thesis may be especially valuable for professionals who develop interventions. In this thesis it was shown that effective exercise interventions do not need by definition to be very long. A duration of six weeks seems to be a minimal recommendation for exercise intervention duration in practice. As it seems important that participants maintain regular exercising on the longer term, I suggest that professionals also stimulate participants' exercise behaviour after the intervention has ended. Furthermore, as intervention compliance proved to be a prerequisite for obtaining (most) beneficial effects, it is important to offer the exercise intervention in a way that it is feasible for participants to adhere to, for example by adjusting the exercise type (e.g., cycling) to the capacity of the participants.

In primary care, exercise fits into a 'stepped care' approach for the treatment of burnout. This means that care is offered not earlier or more intensely than necessary and not later or less intensely than needed. Exercise may be included in guidelines as one of the options that should be (first) prescribed or offered to people who show early signs of burnout. In an ideal situation, general practitioners or occupational physicians may refer fatigued individuals to professionals who can deliver such an exercise intervention. For instance, in some countries (e.g., The Netherlands, Belgium and Germany) running therapists do exist, who are especially trained in supervising exercise for people experiencing burnout symptoms.

NEDERLANDSE SAMENVATTING

DUTCH SUMMARY

Werkgerelateerde vermoeidheid en burnout

Veel werknemers hebben last van een hoge mate van vermoeidheid (schatting: 18% van de werknemers in Europa). Vermoeidheid is een subjectief gevoel van verminderde capaciteit om mentale of fysieke activiteiten te voltooien. Vermoeidheid onder werknemers ontstaat vaak door langdurige stress op het werk. Deze vorm van vermoeidheid wordt daarom ook wel werkgerelateerde vermoeidheid genoemd. Werkgerelateerde vermoeidheid kan het beste begrepen worden als een continuüm, variërend van acute vermoeidheid die ontstaat na een werkdag en weer verdwijnt na een relatief korte rustperiode, tot een ernstige en langdurige vorm van vermoeidheid die ontstaat na een lange periode van (werk)stress. Burnout is het eindstadium van dit continuüm waarbij een werknemer (vaak) niet meer in staat is om te werken. In dit proefschrift worden de termen werkgerelateerde vermoeidheid of hoge mate van vermoeidheid gebruikt. Deze termen refereren naar een serieuze vorm van voortdurende vermoeidheid die ontstaat door langdurige stress op het werk.

Werkgerelateerde vermoeidheid heeft substantiële negatieve effecten op welzijn en gezondheid, zoals verminderd cognitief functioneren en een hoger risico op hart- en vaatziekten. Werkgevers ervaren ook negatieve consequenties, zoals verminderde productiviteit, ziekteverzuim en presenteïsme (doorwerken bij ziekte). Schattingen van jaarlijkse kosten voor de samenleving door werkgerelateerde vermoeidheid variëren van 136.4 miljoen dollar (Verenigde Staten) tot 200 miljoen euro (Europa). Gezien de hoge prevalentie en de negatieve gevolgen voor werknemers, werkgevers en samenleving, is het zinvol om remedies te onderzoeken om werkgerelateerde vermoeidheid tegen te gaan.

Lichaamsbeweging en werkgerelateerde vermoeidheid

In dit proefschrift is lichaamsbeweging (in het Engels: 'exercise') onderzocht als een mogelijke effectieve remedie tegen werkgerelateerde vermoeidheid. Voordelen van deze aanpak is dat lichaamsbeweging gemakkelijk gerealiseerd kan worden, niet veel geld kost en positieve 'bijwerkingen' heeft, zoals een lagere kans op hart- en vaatziekten. Er zijn verschillende verklaringen waarom lichaamsbeweging vermoeidheid zou kunnen verminderen, maar deze zijn (grotendeels) nog niet bewezen. Waarschijnlijk berust de werking op een combinatie van psychologische (bijvoorbeeld omdat lichaamsbeweging loskomen van het werk bevordert) en fysiologische (bijvoorbeeld omdat regelmatig bewegen mensen fitter en daardoor weerbaarder tegen stress) mechanismen.

Ondanks dat eerder empirisch onderzoek het idee ondersteunde dat lichaamsbeweging werkgerelateerde vermoeidheid kan verminderen, waren uitspraken over oorzaak en gevolg nog niet goed mogelijk. Deze kennis was namelijk vooral gebaseerd op correlationele studies. Verder hadden eerdere interventiestudies methodologische tekortkomingen en waren er bij deze interventiestudies geen procesevaluaties uitgevoerd. Ook werd er in deze eerdere studies geen rekening gehouden met de mogelijkheid dat vermoeidheid er ook voor kan zorgen dat werknemers minder bewegen.

Doel van dit proefschrift

In het licht van het bovenstaande was het doel van dit proefschrift om te onderzoeken of lichaamsbeweging werkgerelateerde vermoeidheid kan verminderen. Om dit doel te bereiken werden er drie empirische studies uitgevoerd. Deze studies hadden een sterke methodologie en ondervingen belangrijke tekortkomingen in eerder onderzoek, namelijk: i) gebrek aan goed opgezette interventie studies; ii) gebrek aan procesevaluaties bij deze interventiestudies; en iii) gebrek aan aandacht voor een mogelijke wederkerige relatie tussen lichaamsbeweging en werkgerelateerde vermoeidheid. De resultaten van de drie studies zullen besproken worden in het licht van deze drie tekortkomingen.

Effectevaluaties van de interventiestudies

Twee gerandomiseerde gecontroleerde trials (Engels: RCT; Randomized Controlled Trial) werden uitgevoerd om de eerste tekortkoming van eerder onderzoek te ondervangen (gebrek aan goed opgezette interventie studies). In een RCT wordt randomisatie toegepast, is er een controlegroep en een longitudinale data collectie, waardoor causale gevolgtrekkingen beter te maken zijn. In beide RCT's werden er mensen onderzocht die sterk vermoeid waren. Ze werden random toegewezen aan een interventie- (lichaamsbeweging) of een controlegroep (wachtlijst). Hierdoor was het mogelijk om het effect van lichaamsbeweging op werkgerelateerde vermoeidheid te onderzoeken in vergelijking met het natuurlijk beloop van vermoeidheid. De interventie bestond uit zes weken begeleid (twee keer per week 1 uur) en onbegeleid (een keer per week 1 uur) hardlopen op een lage intensiteit.

De effectevaluatie van *Studie 1* is gerapporteerd in **Hoofdstuk 2**. Deelnemers waren studenten die last hadden van studiegerelateerde vermoeidheid maar die nog wel in staat waren om te studeren. Studiegerelateerde vermoeidheid is vermoeidheid die het gevolg is van langdurige studiestress en is daarom vrij goed vergelijkbaar met werkgerelateerde vermoeidheid. De hardloopinterventie bleek inderdaad te leiden tot een vermindering van studiegerelateerde vermoeidheid (kleine tot middelgrote effectgrootten). De deelnemers in *Studie 2* (zie **Hoofdstuk 3:** studieprotocol; **Hoofdstuk 4**: effectevaluatie) waren werknemers met werkgerelateerde vermoeidheid die nog in staat waren om te werken. Wanneer alle deelnemers van Studie 2 werden geïncludeerd in de analyses, werd er geen verschil in werkgerelateerde vermoeidheid tussen de hardloopgroep en de controlegroep gevonden. Echter, het bleek dat 29% van de 'hardlopers' niet startte of afhaakte tijdens de interventie, en dat 21% van de controle-proefpersonen niet – zoals de bedoeling was – wachtte, maar juist meer ging bewegen tijdens de wachtperiode. Als de 'echte' hardlopers en de 'echte' controle-proefpersonen met elkaar vergeleken werden, werd er een vermindering in werkgerelateerde vermoeidheid gevonden bij de 'hardlopers' (middelgrote effectgrootte). Dit resultaat impliceert dat de hardloopinterventie werkt voor diegenen die daadwerkelijk (genoeg) aan de interventie deelnemen.

In de twee studies werden ook gunstige effecten van de interventie op andere uitkomsten gevonden. Zowel onder studenten als onder werknemers werden verbeteringen in slaapkwaliteit, (zelfgerapporteerd) cognitief functioneren, arbeidsvermogen (deze uitkomst was alleen gemeten onder werknemers) en verminderde subjectieve kosten tijdens de cognitieve testen gevonden. Geen effecten werden gevonden voor de uitkomsten geloof in eigen kunnen, slaapduur, (de meeste) objectieve indicatoren van cognitief functioneren en fysieke fitheid. Het is mogelijk dat een andere dosis van lichaamsbeweging nodig is om deze laatstgenoemde uitkomsten te beïnvloeden. In beide studies waren de gevonden interventie-effecten blijvend, d.w.z. in ieder geval tot 12 weken na afloop van de interventie. Sterker nog, kleine verdere verbeteringen in studie- en werkgerelateerde vermoeidheid werden gevonden in de 12 weken na afloop van de interventie. Voor degenen die lichamelijk actief bleven tijdens de 12 weken follow-up, werden er nog verdere verbeteringen gevonden in fysieke fitheid (studenten) en herstelbehoefte (werknemers).

Procesevaluatie bij interventiestudies

Een effectevaluatie van een interventie – een vergelijking van uitkomsten voor en na een interventie – geeft inzicht in 'of' de interventie werkt, maar niet 'wanneer, hoe en waarom' dit het geval zou kunnen zijn. Het doel van een procesevaluatie is om de 'black box' van de interventieperiode te openen om te kijken wat voor processen er plaatsvinden die mogelijk ook een verklaring vormen voor de gevonden effecten. Voorbeelden van processen die onderzocht kunnen worden zijn implementatie (de manier waarop een interventie in de praktijk wordt gebracht), de aanwezigheid bij en waardering van de interventie door de deelnemers en de setting waarin de interventie wordt uitgevoerd. Het onderzoeken van zulke processen helpt om interventie-effecten te begrijpen. In eerdere beweeginterventies voor werkgerelateerde vermoeidheid werd zulke procesevaluaties niet uitgevoerd.

Om de tweede tekortkoming in eerder onderzoek te ondervangen (gebrek aan procesevaluaties bij interventiestudies), werd de 'black box' van de interventieperiode van *Studie 1* en *Studie 2*[1] geopend. Deelnemers werden voorafgaand aan, vijf keer tijdens en onmiddellijk na afloop van de interventieperiode gevraagd naar welzijnsindicatoren en procesfactoren. In *Studie 1* (zie **Hoofdstuk 5**) werden er zes welzijnsindicatoren bij zowel 'hardlopers' als 'controle-proefpersonen' gemeten (vermoeidheid, energie, stress, gezondheid, tevredenheid en geloof in eigen kunnen). Procesfactoren werden alleen

1 Resultaten van de procesevaluatie van werknemers zijn geen onderdeel van dit proefschrift (manuscript in voorbereiding).

onder 'hardlopers' gemeten. Deze omvatten 'blootstelling' (de hoeveelheid bijgewoonde hardlooptrainingen) en de ervaringen van deelnemers met de interventie (hoeveel plezier er ervaren werd tijdens de hardlooptrainingen en in hoeverre ze tijdens het hardlopen in staat waren los te komen van studie). Er werd onderzocht: i) of de blootstelling aan de hardlooptrainingen gerelateerd was aan verschillen in welzijnstrajecten tussen deelnemers; ii) de minimale blootstelling aan de hardlooptrainingen die nodig was om verschil te zien tussen de interventie- en de controlegroep; en iii) of ervaringen tijdens het de hardloopinterventie (plezier en loskomen van studie) gerelateerd waren aan verschillen in welzijnstrajecten.

Wat betreft blootstelling, was er over het algemeen een hoge deelname aan de hardlooptrainingen. Echter, een toename in geloof in eigen kunnen werd alleen gevonden bij diegenen die (bijna) alle hardlooptrainingen bijwoonden. Mogelijk vormt de hoge deelname en de lage variatie hierin een verklaring waarom er geen significante verschillen in andere welzijnsindicatoren zijn gevonden.

Wat betreft de minimale blootstelling aan de hardlooptrainingen, vonden we dat studenten-hardlopers minder vermoeid waren dan controle-proefpersonen vanaf twee interventieweken. Voor energie en tevredenheid, werden gunstige effecten van hardlopen zichtbaar vanaf de vierde interventieweek. Samen geven deze resultaten aan dat gunstige interventie-effecten al relatief snel zichtbaar worden. Echter, deze effecten geven statistische verschillen aan, maar hoeven nog geen klinisch relevante effecten te betekenen. Een interventieduur van zes weken lijkt een minimale benodigde interventieduur met het oog op klinisch relevante effecten.

Aangaande de ervaringen van deelnemers vonden we dat loskomen van studie-eisen een ervaring was die bijdroeg aan interventie-succes: deelnemers die beter konden loskomen van hun studie tijdens het hardlopen lieten een grotere afname in stress en vermoeidheid en een grotere toename in energie zien vergeleken met deelnemers die dit minder goed konden. Welzijnstrajecten verschilden niet op basis van hoeveel plezier deelnemers tijdens het hardlopen ervoeren. Het bleek echter dat deelnemers het hardlopen over het algemeen al als plezierig ervoeren, vanaf het begin van de interventie. Door het gebrek aan variatie in de mate van plezier, is het waarschijnlijk ook moeilijk om verschillen in welzijnstrajecten op basis van deze ervaring te vinden.

Lichaamsbeweging en werkgerelateerde vermoeidheid: een wederkerige relatie?

In eerder onderzoek naar de relatie tussen lichaamsbeweging en werkgerelateerde vermoeidheid was voornamelijk een eenzijdige relatie onderzocht: vermindert lichaamsbeweging werkgerelateerde vermoeidheid? Het is echter ook mogelijk dat de relatie tussen lichaamsbeweging en vermoeidheid wederkerig is. Dit betekent dat lichaamsbeweging een impact kan hebben op vermoeidheid, maar dat vermoeidheid ook de mate van lichaamsbeweging kan belemmeren. Gezien het cross-sectionele karakter van eerdere studies, kon de precieze richting in de relatie tussen lichaamsbeweging en vermoeidheid niet vastgesteld worden.

Tegen deze achtergrond werd *Studie 3* uitgevoerd, een longitudinale studie met twee meetmomenten (full-panel design) waar een jaar tijd tussen zat (zie **Hoofdstuk 6**). Dit design kan een temporele sequentie en een statistische associatie aantonen – beide zijn nodig om een causale relatie aan te tonen. Steun werd gevonden voor een wederkerige relatie tussen lichaamsbeweging en werkgerelateerde vermoeidheid: meer lichaamsbeweging was gerelateerd aan een lagere niveau van werkgerelateerde vermoeidheid een jaar later, en een hoger niveau van werkgerelateerde vermoeidheid was gerelateerd aan een lager niveau van lichaamsbeweging een jaar later. Dit gevonden resultaat wijst naar een gunstige rol van lichaamsbeweging voor het verminderen van werkgerelateerde vermoeidheid, maar geeft ook aan dat vermoeidheid werknemers hindert in hun mate van lichaamsbeweging. Het resultaat kan zelfs wijzen op een vicieuze cirkel waarin werkgerelateerde vermoeidheid leidt tot minder lichaamsbeweging en deze verminderde lichaamsbeweging weer tot meer werkgerelateerde vermoeidheid enzovoorts.

We vergeleken ook twee betekenisvolle groepen die veranderden in lichaamsbeweging over een jaar tijd. Deze groepen waren gebaseerd op de beweegnorm (≥5 dagen 30 minuten matig intensief bewegen). Werknemers die veranderden in het voldoen aan de beweegnorm over een jaar tijd lieten veranderden niet maar lieten vrij stabiele niveaus van werkgerelateerde vermoeidheid zien. Een mogelijke verklaring voor dit resultaat is dat de nogal 'grove' dichotomie op basis van het voldoen aan de beweegnorm het onmogelijk maakt om kleine veranderingen in bewegen en potentiële bijkomende veranderingen in vermoeidheid te laten zien.

Methodologische beperkingen in dit proefschrift

Twee methodologische beperkingen moeten besproken worden om de resultaten in dit proefschrift adequaat te interpreteren. Ten eerste werd er een wachtlijst als controlegroep in *Studie 1* en *Studie 2* gebruikt (wachtlijst design). Een wachtlijst design is geschikt voor een eerste evaluatie van een nieuwe interventie, maar op basis van dit design kan het niet uitgesloten worden dat niet-specifieke factoren bijdragen aan – of zelfs verantwoordelijk zijn voor – de gevonden effecten. Een niet-specifieke factor is een element van de interventie dat niet gespecificeerd is in de interventie theorie, maar mogelijk wel heeft geresulteerd in gunstige interventie-effecten. Potentiële niet-specifieke factoren in onze studies kunnen placebo-effecten (verwachtingen van deelnemers over de effectiviteit van de interventie), sociale steun en aandacht van de onderzoekers, mede-deelnemers en trainers zijn. Het is echter niet plausibel dat de gevonden effecten alleen door deze niet-specifieke factoren veroorzaakt zijn, aangezien de effecten blijvend waren en meer lichaamsbeweging gerelateerd was aan grotere interventie-effecten. Vervolgonderzoek zou zich kunnen richten op de bijdrage van zulke niet-specifieke factoren aan het effect van lichaamsbeweging op vermoeidheid.

Ten tweede is het nodig om de gebruikte meetmethoden van lichaamsbeweging en slaap te bespreken. In *Studie 1* en *Studie 2* werd de intensiteit van lichaamsbeweging niet objectief gemeten (bijvoorbeeld met behulp van hartslagmeters), alhoewel zulke meetmethoden het meest accuraat zijn. Slaap werd ook niet objectief gemeten (bijvoorbeeld met behulp van actigrafie), terwijl zulke meetmethoden een gedetailleerder inzicht kunnen geven in slaap. Verder werd er in Studie 3 maar één item gebruikt om lichaamsbeweging te meten. Dit zelfgerapporteerde item kan er toe hebben geleid dat de mate van lichaamsbeweging onder- of overschat werd. Bovendien konden we zo niet het exacte type, frequentie, duur, intensiteit en timing (bijvoorbeeld tijdens of buiten werk) van lichaamsbeweging bepalen dat nodig is om werkgerelateerde vermoeidheid te verminderen. Toekomstig onderzoek zou beter gevalideerde en gedetailleerde objectieve en subjectieve meetmethoden kunnen gebruiken om lichaamsbeweging en slaap doorgrondig te meten.

Toekomstig onderzoek

Er kunnen vier richtingen voor toekomstig onderzoek geformuleerd worden. Ten eerste raad ik replicatie-studies aan in verschillende settingen en populaties om de resultaten die gevonden zijn in dit proefschrift nog beter te generaliseren naar een grotere populatie. Werknemers met klinische burnout – het 'eind-stadium' van werkgerelateerde vermoeidheid – of vermoeide werknemers die al veel in beweging zijn, zijn mogelijke interessante deelnemers.

Ten tweede adviseer ik dat toekomstige interventie-onderzoeken relevante procesfactoren includeren bij het evalueren van interventies, omdat procesevaluaties essentieel zijn om effecten accuraat te interpreteren. Ik adviseer om de keuze voor procesfactoren te baseren op theorie en om praktische richtlijnen te gebruiken bij het uitvoeren van deze procesevaluaties.

Ten derde is er meer onderzoek nodig om de werking van lichaamsbeweging op vermoeidheid te begrijpen. Dit helpt in theorievorming en het ontwerpen van toekomstige interventies. Ik raad aan om de al veronderstelde psychologische (bijvoorbeeld de afleidingshypothese) en fysiologische (bijvoorbeeld de cardiovasculaire fitheidshypothese) werkingsmechanismen te onderzoeken. Op basis van dit proefschrift zouden ook slaap en cognitief functioneren twee mogelijke plausibele werkingsmechanismen kunnen zijn.

Ten vierde is meer onderzoek wenselijk naar de beste dosis (frequentie, intensiteit en duur), type (welke vorm van lichaamsbeweging) en timing (tijdens werk of in de vrije tijd) van lichaamsbeweging om werkgerelateerde vermoeidheid te verminderen. Meer inzicht in de dosis, type en timing kan professionals (in wetenschap en praktijk) helpen bij het ontwikkelen van toekomstige effectieve interventies.

Praktische aanbevelingen

Op basis van dit proefschrift kunnen er verschillende praktische aanbevelingen gedaan worden. Dit kan gedaan worden op individueel, organisatie-, gezondheidszorg- en beleidsniveau. Op individueel niveau, raad ik vermoeide studenten en werknemers aan om regelmatig aan lichaamsbeweging te doen. Ik adviseer om te starten met regelmatig bewegen op een lage intensiteit. Een lage intensiteit betekent dat een gesprek voeren nog mogelijk moet zijn tijdens lichaamsbeweging. Het gedoseerd opbouwen van hardlopen zoals is gedaan in de interventiestudies in dit proefschrift is een goed voorbeeld voor het opbouwen van regelmatig bewegen (zie Appendix C voor een hardloopschema). Ik adviseer ook om lichaamsbeweging op zo'n manier in te richten dat loskomen van studie of werk bevorderd wordt, bijvoorbeeld door te bewegen in de natuur. Het kiezen van een plezierige vorm van lichaamsbeweging kan helpen om dit gezonde gedrag vol te houden op de langere termijn. Voor (vermoeide) studenten en werknemers die al regelmatig bewegen, beveel ik aan om dit vooral vol te houden (het is een 'goede gewoonte'), maar zonder te overdrijven (te veel of te hard).

Op organisatieniveau, raad ik aan dat werkgevers investeren in zowel primaire als secundaire preventie. Primaire preventie vindt plaats voordat ziekte (bijvoorbeeld burnout) ontstaat en zorgt er dus voor dat een ziekte niet ontstaat. Secundaire preventie is erop gericht om in te grijpen bij vroege symptomen van een ziekte, zodat de ziekte zich niet verder kan ontwikkelen. Beide preventiestrategieën kunnen gericht worden op de werksituatie en op het individu. Een voorbeeld van een werkgerichte primaire preventie om werkgerelateerde vermoeidheid tegen te gaan is door taakeisen (bijvoorbeeld de hoeveelheid en de moeilijkheidsgraad van werk) uitdagend maar niet te hoog te maken. Lichaamsbeweging past bij individugerichte preventiestrategieën. Werkgevers zouden lichaamsbeweging kunnen stimuleren om zo het risico op werkgerelateerde vermoeidheid of burnout te verminderen, bijvoorbeeld door sportfaciliteiten aan te bieden op het werk (= individugerichte primaire preventie). Daarnaast zouden werkgevers vermoeide werknemers (die dus risico lopen op het ontwikkelen van een burnout) de mogelijkheid kunnen bieden om mee te doen met een beweegprogramma (= individugerichte secundaire preventie).

Vergelijkbare aanbevelingen wat betreft primaire en secundaire preventie gelden voor (hoger) onderwijsinstellingen, zoals universiteiten. Deze instellingen zouden ervoor moeten zorgen dat de studielast voor studenten uitdagend maar niet te hoog is. Ook kunnen studenten aangemoedigd worden om gebruik te maken van sportfaciliteiten. Studieadviseurs en/of studentenpsychologen zouden een beweegprogramma kunnen aanbieden voor studenten die last hebben van vroege burnoutsymptomen (studiegerelateerde vemoeidheid).

Op het niveau van gezondheidszorg en beleid zijn de resultaten van dit proefschrift waardevol voor professionals die interventies ontwikkelen. In dit proefschrift werd duidelijk dat een effectieve interventie voor werkgerelateerde vermoeidheid niet per definitie heel lang hoeft te zijn. Een interventieduur van zes weken lijkt een minimale duur te zijn voor effectiviteit in de praktijk. Omdat het belangrijk lijkt dat deelnemers lichaamsbeweging blijven volhouden op de lange termijn, raad ik aan dat professionals ook lichaamsbeweging van deelnemers na de interventieperiode monitoren en stimuleren. Bovendien, aangezien een hoge deelname aan de interventie een voorwaarde was om (de meest) gunstige effecten te zien, is het belangrijk om te interventie zo aan te bieden dat een hoge deelname haalbaar is, bijvoorbeeld door het type lichaamsbeweging aan te passen aan de belastbaarheid van de deelnemer(s) (bijvoorbeeld fietsen in plaats van hardlopen).

In de eerstelijnszorg past lichaamsbeweging in een 'stepped care' aanpak van burnout. Dit betekent dat zorg niet eerder of intensiever wordt aangeboden dan nodig is en niet later of minder intensief dan nodig is. Lichaamsbeweging zou opgenomen kunnen worden in de richtlijnen voor overspanning en burnout als een van de eerste behandelopties bij mensen die vroege burnout-klachten vertonen. Idealiter zouden huisartsen of bedrijfsartsen vermoeide werknemers en studenten moeten verwijzen naar professionals die een beweeginterventie kunnen uitvoeren. In sommige landen (bijvoorbeeld Nederland, België en Duitsland) bestaan er running therapeuten die speciaal opgeleid zijn om mensen met burnout-klachten te begeleiden met hardlopen.

DANKWOORD

Dankwoord

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ABOUT THE AUTHOR

Juriena de Vries was born on August 18th 1988 in Delft (the Netherlands). Juriena studied Psychology at the Leiden University. During her study, she was looking for a way to combine her study with her passion for sports. She chose to do the Master Clinical Psychology and started her own company (Run your Mind) in physical training for people with psychological complaints. Even though she enjoyed working in practice, pursuing research also interested her. During the Research Master Clinical and Health Psychology, Juriena discovered that doing research perfectly fits her qualities and interests. After finishing the Research Master, a dream came true: she accepted a PhD position at the Behavioural Science Institute (BSI) of the Radboud University in Nijmegen. At the BSI she worked in the Work, Health and Performance group and performed research on exercise and employee well-being. She combined this PhD project with triathlon at a national level. Since January 2017, Juriena is employed as an Assistant Professor at the Department of Work and Organizational Psychology at the Erasmus University in Rotterdam. In Rotterdam she will continue her work on exercise and employee well-being.

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