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Being stressed and active!?

An analysis of different aspects of the relationship between physical activity, individual perceived stress, and individual health

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von

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Publications of the Dissertation

Parts of the following dissertation have been published or submitted in national and international peer-reviewed journals in translation or original with approval of Prof. Dr. Alexander Woll.

Publications:

Reiner, M., Niermann, C., Jekauc, D. & Woll, A.. (2013). Long-term health benefits of physical activity – a systematic review of longitudinal studies, *BMC Public Health, 13,* 813.

Reiner, M., Niermann, C., Krapf, F. & Woll, A., (2013). Stress, Sport und Beschwerdewahrnehmung – Puffereffekte von Sport und körperlicher Aktivität. *Sportwissenschaft, 2013* (2), S. 264 - 275.

Reiner, M., Niermann, C., Krapf, F. & Woll, A., (under review) Stress: personal matter or family affair? Intra- and inter-individual relationships between stress, physical activity, sedentary behavior, and nutrition (in second revision at *International Journal of Child, Youth, and Family Studies*).

Reiner, M., Niermann, C., Krapf, F., Stults-Kolehmainen, M. & Woll, A., On the move or on standby? A day-level study on the effects of stress on physical activity. (In preparation for *Psychology of Sport and Exercise*).

Conference proceedings and publications:

Reiner, M., Niermann, C., Krapf, F. & Woll, A. (2013). Selbstwahrgenommener Stress, Beschwerden und Sportaktivität. In M. Wegener, J.-P. Brückner & S. Kratzstein (Hrsg.), *Sportpsychologische Kompetenz und Verantwortung. 44. Jahrestagung der Arbeitsgemeinschaft Sportpsychologie (asp) vom 17. - 19. 05. 2012 in Kiel / Oslo* (S. 127). Hamburg: Feldhaus Edition Czwalina.

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Zusammenfassung und Summary

Zusammenfassung:

Stress entwickelte sich in den letzten Jahrzehnten zu einem weltweiten und alle Teile der Bevölkerung betreffenden Phänomen. Zusätzlich zur weiten Verbreitung ist erlebter Stress eine der bedeutendsten Ursachen für physische und psychische Beschwerden. Aus diesem Grund rücken in den letzten Jahren erlebter Stress und seine gesundheitlichen Folgen sowie die daraus resultierenden steigenden stressbedingten Gesundheitskosten in den Fokus der aktuellen Gesundheitsforschung. Auf der Suche nach effektiven und kostengünstigen Präventions- und Rehabilitationsmaßnahmen für stressbedingte Gesundheitsbeschwerden rücken sportliche und körperliche Aktivitäten in den Fokus. Wenn Stress negative Auswirkungen auf die Gesundheit hat, im Gegensatz dazu Sport und körperliche Aktivität gesundheitsförderlich sind, stellt sich die Frage, welche Rolle Sport und körperliche Aktivität im Zusammenhang mit erlebtem Stress spielen können? Diese zentrale Frage wird im Rahmen dieser Dissertation näher beleuchtet.

Fuchs, Hahn und Schwarzer (1994) entwickelten ein grundlegendes Rahmenmodell zur Beschreibung und Einordnung möglicher Wirkungen von Sport und körperlicher Aktivität im Wechselspiel zwischen wahrgenommenem Stress, verfügbaren individuellen Ressourcen und gesundheitlichen Konsequenzen Dabei wurde erkannt, dass Sport sowohl in direkter Beziehung zu den einzelnen Parametern stehen kann, als auch die Beziehungen zwischen den Parametern moderierend beeinflussen kann. Dieses Modell fungiert als Rahmen der Dissertation im Ganzen und zur Verortung der einzelnen Publikationen.

Die Beziehung zwischen Sport und Gesundheit ist weitreichend belegt – sportliche und körperliche Aktivität wirken sowohl präventiv, als auch rehabilitativ auf die persönliche, physische und psychische Gesundheit (Bouchard, Blair & Haskell, 2012; Dishman, Washburn & Heath, 2004). Ein systematisches Literaturreview (Kapitel 2) fasst langzeitliche Effekte von Sport auf die Entwicklung von Risikofaktoren wie Gewichtszunahme und Übergewicht

und drei weit verbreitete Krankheitsbilder, Herz-Kreislauf-Erkrankungen, Diabetes Mellitus Typ 2 und Alzheimer und Demenz zusammen. Es zeigt sich, dass Sport bezüglich aller untersuchten Risikofaktoren und Krankheiten positive Wirkungen hat. Jedoch, so legt die Literatur nahe, kann Sport nur seine ideale gesundheitsfördernde Wirkung entfalten, wenn regelmäßig und häufig, mit gewisser Mindestintensität und Dauer trainiert wird.

Betrachtet man den Zusammenhang zwischen erlebtem Stress und sportlicher Aktivität im Rahmenmodell von Fuchs, Hahn und Schwarzer (1994), so zeigt sich, dass Sport sowohl als Moderator als auch Mediator auf die Gesundheit diskutiert wird.

Diesen Moderator- bzw. Puffereffekt von Sport auf gesundheitsbezogene physische und psychische Auswirkungen von Stress untersucht Studie 1. Die Studie unterscheidet dabei zwischen sportlicher und körperlicher Aktivität, sowie zwischen verschiedenen Beschwerdeformen (z.B. physische und psychische Beschwerden wie Erschöpfung, Magenschmerzen oder Herzbeschwerden). Die Ergebnisse weisen einen Puffereffekt von Sport, nicht jedoch von körperlicher Aktivität, nach, d.h. erlebt eine Person viel Stress, kann sportliche Aktivität, nicht aber körperliche Aktivität, die resultierenden physischen und psychischen Beschwerden abmildern. Bezüglich der untersuchten verschiedenen Beschwerdeformen zeigt sich, dass Sport nicht einheitlich für alle Beschwerdeformen seine puffernde Wirkung entfalten kann. Sport scheint etwas stärker für physische, im Gegensatz zu psychischen, Beschwerdeformen wirken zu können. Über die Pufferwirkung von Sport hinausgehend zeigen die Ergebnisse, dass weitere (Modertor-)Variablen, wie zum Beispiel das Alter oder Geschlecht der untersuchten Teilnehmer, sowohl auf die untersuchten Variablen selbst als auch auf den Zusammenhang zwischen ihnen, und den Puffereffekt von Sport Einfluss haben.

Deutlich wird in dieser Studie, wie bereits im Modell von Fuchs, Hahn und Schwarzer (1994) angenommen, der enge Zusammenhang zwischen Sport und erlebtem Stress. Betrachtet man diesen Zusammenhang näher, so zeigt sich, dass beide Richtungen, d.h. der Effekt von Sport auf die individuelle Stress-

Reaktivität und gegensätzlich dazu der Effekt von erlebtem Stress auf das individuelle Sporttreiben, plausibel und erklärbar sind.

Bezüglich der ersten Wirkrichtung zeigen zahlreiche Untersuchungen, dass sportlich aktive Personen eine deutlich reduzierte Stress-Reaktivität und darüber hinaus eine schnellere Regeneration zum Normalzustand aufweisen. Sport kann somit stressreduzierend wirken.

Bezüglich der zweiten Wirkrichtung, d.h. des Effekts von erlebtem Stress auf die Sportaktivität, sind bestehende Literaturergebnisse uneinheitlich (Stults-Kolehmainen & Sinha, 2014). Da individuelles Verhalten hochgradig von individuellen Wahrnehmungen beeinflusst wird, betrachtet diese Dissertation in zwei Studien auch diese Wirkrichtung zwischen erlebtem Stress und Sportaktivität.

Um die Auswirkungen von erlebtem Stress auf die individuelle Sportaktivität systematisch zu untersuchen, ist zunächst die Darstellung und Verortung in einem theoretischen Rahmenmodell, der „Social Cognitive Theory", notwendig. Das zentrale Element von Banduras „Social Cognitive Theory" ist die triadische reziproke Interaktion zwischen der Person selbst mit ihren spezifischen Charakteristika, wie Wahrnehmungen, Stimmungen und Werten, ihrem Verhalten und ihrer sozialen und materiellen Umwelt. Die Annahme reziproker Interaktionen verdeutlicht, dass individuelles Verhalten nicht losgelöst von Eigenschaften der Person selbst oder der umgebenden Umwelt betrachtet werden kann. Das heißt, im Rahmen der „Social Cognitive Theory" entsteht Stress in den Interaktionen der drei Elemente und hat gleichzeitig Auswirkungen auf die drei Elemente selbst (wie zum Beispiel auf das Verhalten).

Zur Verdeutlichung stellt diese Dissertation Literaturergebnisse hinsichtlich der Auswirkungen von Stress auf die Person selbst, ihr Verhalten und ihre Umwelt dar. Die dargestellten Literaturbefunde verdeutlichen, dass insbesondere chronischer Stress zumeist negative Wirkungen auf die physische und psychische Gesundheit der Person, sowie auf ihr Verhalten hat (El Ansari, Oskrochi & Stock, 2013; Everly Jr. & Lating, 2012; Werner, Frost, Macnee, McCabe & Rice, 2012). Die Umgebung wird zumeist durch diese stressbedingten Verhaltensänderungen beeinflusst, d.h. ist eine Person gestresst verhält sie sich in Interaktionen mit Personen im gemeinsamen sozialen Kontext anders, was wiederum Wirkungen auf das Verhalten der anderen Personen hat. Ein Beispiel hierfür sind z.B. veränderte interfamiliäre Interaktionen, d.h. ist ein Elternteil gestresst verändert sein individuelles Verhalten, z.B. Nähe, Gefühl der Geborgenheit, Bestrafungen bei Konflikten, gegenüber anderen Familienmitgliedern (McBride, Schoppe & Rane, 2002; Randall & Bodenmann, 2009). Die Familie ist die wichtigste soziale Umgebung, in der wir leben. Im Rahmen der familiären Sozialisation lernen Kinder gesundes Verhalten, aber auch den Umgang mit Stress. Hat Stress nun verhaltensändernde Wirkungen, so wird sich dieser auch im Rahmen der Familie zeigen, was wiederum Auswirkungen auf andere Familienmitglieder und deren Gesundheitsverhalten haben dürfte.

Studie 2 untersucht aus diesem Grund sowohl intra- als auch inter-individuelle Effekte von wahrgenommenem Stress auf die sportliche Aktivität, inaktive Verhaltensweisen (Sedentary Behavior) und die Ernährung in der Familie. Die intra-individuellen Ergebnisse, d.h. die Ergebnisse bezüglich der Effekte von wahrgenommenem Stress auf das Gesundheitsverhalten der jeweiligen Person selbst, zeigen auf, dass die Familienmitglieder sich sehr stark hinsichtlich der Richtung und Stärke der Effekte unterscheiden. Zum Beispiel führt bei Müttern erlebter Arbeitsstress zu höherem Konsum von ungesunden Lebensmitteln und geringem Konsum von gesunden Lebensmitteln. Die Analyse von sozialem Stress zeigt genau entgegengesetzte Ergebnisse – höherer sozialer Stress geht mit höherem Konsum von gesunden Lebensmitteln und geringem Konsum von ungesunden Lebensmitteln einher. Beim Kind und Vater zeigen sich diese Ergebnisse nicht. Dieses Ergebnis zeigt beispielhaft, dass Stress und seine Wirkungen sehr individuell sind und eventuell das Alter und Geschlecht der Personen eine wichtige Rolle spielen. Hinsichtlich der inter-individuellen Zusammenhänge, d.h. die Ergebnisse bezüglich der Effekte von wahrgenommenem Stress auf das Gesundheitsverhalten anderer Familienmitglieder, zeigen sich drei zentrale Ergebnisse: Zum einen scheint die Mutter die wichtigste gesundheitsrelevante Person der Familie zu sein, d.h. ihr Stresserleben zeigt Zusammenhänge mit dem Gesundheitsverhalten der andern Familienmitglieder. Zum zweiten beeinflussen sich die Eltern gegenseitig, d.h. erlebt einer der Partner, in diesem Fall der Vater, mehr Stress, verbringt der andere Partner, in diesem Fall die Mutter, weniger Zeit mit inaktiven Tätigkeiten. Als drittes zentrales Ergebnis zeigt sich, dass das Stresserleben des Kindes Zusammenhänge mit den Verhaltensweisen der Eltern. Diese Wirkrichtung wurde bislang noch nicht untersucht. Zusammenfassend ergeben die Ergebnisse der Studie sowohl auf intra-individueller als auch auf inter-individueller Ebene deutliche individuelle Zusammenhänge von wahrgenommenem Stress mit individuellem Gesundheitsverhalten.

Diese Individualität bezüglich der Stresswahrnehmung und ihrer Auswirkungen auf die Sportaktivität sowie der zeitlichen Instabilität der Variablen untersucht Studie 3 mittels eines Tagebuchansatzes. Personenspezifische Analysen der täglichen Aktivität in Relation zu erlebtem Stress am selben Tag ergeben drei unterschiedliche Gruppen: *Reducers* (n=37) verringern ihren Energieverbrauch an stressreichen Tagen um durchschnittlich 340,38 kcal im Vergleich zu stressarmen Tagen; im Unterschied dazu steigern *Increasers* (n=34) ihren Energieverbrauch an stressreichen Tagen um durchschnittlich 382,62 kcal im Vergleich zu stressarmen Tagen und *Maintainers* (n=20) verändern ihren Energieverbrauch nur minimal. Diese detaillierte personenspezifische Analyse verdeutlicht die individuell unterschiedlichen verhaltensbezogenen Reaktion der Personen, das bei ausschließlicher statistischer Analyse über alle Teilnehmer hinweg verdeckt geblieben wäre. Diese Individualität scheint die Ursache für inkonsistente Literaturergebnisse zu sein.

Zusammenfassend trägt diese Dissertation zum aktuellen Stand der Forschung bezüglich des Zusammenhangs zwischen wahrgenommenem Stress und Sportaktivität auf vielfache Weise bei: Studie 1 vergleicht den postulierten Puffereffekt zwischen sportlicher und körperlicher Aktivität hinsichtlich verschiedener Beschwerdeformen. Sowohl der Vergleich zwischen sportlicher und körperlicher Aktivität als auch die Unterscheidung verschiedener Beschwerdeformen in einer einzelnen Studie erweitern die bestehende Forschung. Studie 2 unterscheidet auf der einen Seite zwischen verschiedenen Stressursachen und deren Effekten auf gesundheitsrelevante

Verhaltensweisen. Auf der anderen Seite zeigt die Erweiterung der Social Cognitive Theory auf die Familie individuelle Unterschiede zwischen den einzelnen Familienmitgliedern. Studie 3 untersucht schließlich den Effekt von täglich erlebtem Stress auf die tägliche körperliche Aktivität und bezieht somit die zeitliche Fluktuation und Individualität beider Variablen mit ein.

Die Ergebnisse aller Studien verdeutlichen die Individualität sowohl von erlebtem Stress, als auch von sportlicher und körperlicher Aktivität sowie deren Effekte aufeinander. Diese Individualität sollte in weiteren Studien näher beleuchtet werden.

Summary:

Since stress has become an important common phenomenon in most parts of society around the world, the effects of stress on personal health have moved into the focus of research. This link between stress and individual health results in rising amounts of stress-induced physical and mental health problems and diseases, which in turn lead to rising health care costs. In contrast, physical activity is an important factor for the prevention and therapy of health problems and diseases.
Therefore, the purpose of this dissertation is to describe and research different roles and effects of physical activity in the stress-health context.

Fuchs, Hahn, and Schwarzer (1994) developed a basic outline model for different roles of physical activity in the context of stress, personal resources, and personal health. Physical activity is discussed as having different direct and moderating effects affecting the elements themselves, and the relationships between these elements in the model.

An enormous amount of literature presents physical activity as having a positive effect on physical and mental health. A systematic literature review of the long-term effects of physical activity on the risk factors weight-gain and obesity, and three major non-communicable diseases (coronary heart diseases, type 2 diabetes mellitus, and Alzheimer's disease and dementia) are presented and discussed. Overall, physical activity has positive long-term effects on individual health. However, the results of the literature review and further literature indicate, that regularity, intensity, frequency, and duration of physical exercise is necessary to enhance individual health and prevent the development of health problems and diseases.

Regarding the relationship between physical activity and individually perceived stress, the outlining model of Fuchs, Hahn, and Schwarzer (1994) assumes two different effects: a direct relationship with individually perceived stress, discussed in both directions (the effects of physical activity on individual stress reactivity, and in turn, the effects of individual stress on the individual physical

activity), and a moderating effect of physical activity on the effects of individually perceived stress on-personal health.

Study 1 researches the moderating / buffering effects of physical activity, and activities of daily living on the effect of individual perceived stress on various physical and mental health complaints. The results indicate that the energy expenditure spent with physical activity is able to buffer the negative effects of stress. In contrast, energy expenditure spent with activities of daily living has no significant buffering effect. Physical activity alone proved to have a buffering effect. Additionally to the comparison between physical activity and activities of daily living, study 1 differentiates between various physical and mental health complaints. The results indicate that physical activity does not buffer the negative effects of all kinds of health complaints. However, the results show that physical activity is a slightly stronger buffering variable for physical than mental health complaints. Furthermore, the results indicate that further variables such as age and gender affect the variables themselves (individually perceived stress, personal health, and physical activity) and the buffering effect. Additionally, the results indicate, as described in the outline framework of Fuchs, Hahn, and Schwarzer (1994), that physical activity and individually perceived stress are closely related.

Considering the relationship between physical activity and individually perceived stress; both directions, this means, the effect of physical activity on the individual stress reactivity versus the effects of individually perceived stress on the individual physical activity level, are plausible.

On the one hand, physical activity, especially highly intensive physical activity, seems to have positive effects on the individual stress reactivity. This means, physically active people have lower physiological stress reactions and recover faster after a stressful situation when compared ~~to~~ with inactive people (Gerber et al., 2014; Klaperski, von Dawans, Heinrichs & Fuchs, 2013).

In contrast, literature results of the effects of individually perceived stress on individual physical activity are inconsistent (Stults-Kolehmainen & Sinha, 2014). However, since individual behavior is highly affected by individual perceptions, this dissertation concentrates on the effects of individually perceived stress on physical activity.

To locate the effects of perceived stress on physical activity, a theoretical basis, the Social Cognitive Theory (SCT), is presented and discussed. The key element of Banduras' (1989) SCT is the triadic reciprocal interaction between the person, including his individual characteristics (e.g. perceptions, affects, and values) and behavior, and social and material environment. The reciprocal interaction elucidates that individual behavior is constantly interacting with the personal characteristics and the environment the person lives in, reciprocally affecting each other. According to the transactional model of stress (Lazarus & Folkman, 1986), stress is defined as the individual imbalance between the given demand (internal or external) and personal resources (internal or external). Expanding the SCT, stress occurs in the triadic reciprocal interactions between the elements and affects each element in turn (i.e. change of individual behavior due to individually perceived stress). For clarification, the state of the art concerning the effects of individually perceived stress on the person themselves, their behavior, and the environment are demonstrated. Literature indicates that chronically perceived stress has different, mostly negative effects on the physical, physiological, and mental health of the person themselves; on their individual health behavior, and on the individual environment, which is mostly moderated through a changed behavior. The family is the most important social context a person lives in. In the family, children learn healthy behavior and how to cope with stress. Thus, inter-individual effects of perceived stress within the family are important for learning and maintaining healthy behavior.

Study 2 researches intra- and inter-individual effects of perceived stress on physical activity, sedentary behavior, and nutrition in the family. As a first step, the intra-individual effects of stress, meaning the effects of individual perceived stress on the individual health behavior of the same family member, is researched. The results indicate that the effects individually perceived stress due to different sources differ between the researched health behaviors and the family members. This indicates that the perception of stress and its effect are very individual. In a second step, the inter-individual effects of individual perceived stress on the health behaviors of other family members are analyzed. Three main aspects arise: a) The important role of the mother affecting the individual health behavior of other family members; b) the parent dyad affecting

each other; and c) the perceived stress of the child which has effects on the health behavior, especially sedentary behavior, of the parents. The results indicate that the perception of stress and its effects, as well as the social context a person lives in, is very important for individual health behavior.

To capture individual reactions and the time-fluctuation of stress and physical activity, study 3 researches the effects of individual perceived stress on individual physical activity on a day-to-day approach. The detailed results of the seven day diary study show three different groups of participants: Reducers (n=37) lower their energy expenditure by an average of 340.38 kcal when stressed; Increasers (n=34) raise their energy expenditure by an average of about 382.62 kcal, and Maintainers (n=20) do not change their energy expenditure. The results clarify that people react differently on individually perceived stress, which may be the reason for inconsistent research results.

To conclude, the dissertation advances the current literature results according to the effects of physical activity in the stress-health relationship by including various differentiations. Study 1 compares the buffering effects of physical activity and activities of daily living on different physical and mental health outcomes; Study 2 distinguishes between different sources of stress, different health behaviors and different family members by estimating intra- and inter-individual effects of stress. Study 3 contributes to the field of research by taking the time fluctuation of stress and physical activity into consideration. The day-to-day approach elucidates individual effects of individual perceived stress on individual physical activity. Further studies should research this individuality of perceived stress, physical activity, and the relationship between both variables.

Chapter 1: Stress, a common phenomenon

Finally at home after a stressful work day – getting up too early followed by too many work hours, time pressure to finish a project, no lunch break because of a meeting, a demanding boss, a quick meal during the daily traffic jam, no time for the kids – What a Stress! … Now the only thing I want to do is sit on the couch, watch TV, and talk to my partner… Oh no I forgot the jogging session with a friend… I cannot believe that he could go jogging after a stressful work day and feel happy and satisfied afterwards…

In modern society, stress is not a phenomenon of businessmen anymore (Cohen & Janicki-Deverts, 2012; Cooper, 2012), stress is part of the daily life of most people (TK Techniker Krankenkasse, 2013). All age groups, from children up to seniors (Cohen & Janicki-Deverts, 2012; Jantowski & Kretschmar, 2013; Rice, 2012), all social groups (Bergdahl & Bergdahl, 2002; Chandola, 2010; Cohen & Janicki-Deverts, 2012), and both genders (Cohen & Janicki-Deverts, 2012) report stress..

To give some examples of the statistics for Germany: Within the "German Health Interview and Examination Survey for Children and Adolescents" conducted in 2001, every fifth child and every seventh adolescent reported emotional problems (Robert Koch Institut, 2006) which were mostly caused by stress (Shapero & Steinberg, 2013). With progressing age and the start of work life, the amount of stressed people increases – up to 80 % of the 17.562 employees analyzed within the "Stressreport Deutschland" of the German Federal Institute for Occupational Safety and Health (BAuA) report a high amount of stress during normal work days (Lohmann-Haislah, 2012). However, stress is not only confined to the work environment, but is a common phenomenon within normal families. The "AOK Familienstudie" demonstrated, that stress plays an important role in the daily life of families (AOK Bundesverband & SINUS Institut, 2014). 46% of the researched parents perceive stress as a common part of their daily family life. Furthermore, an inadequate work-life balance causes additional stress (Stoeva, Chiu &

Greenhaus, 2002). These are just some results of different studies within different settings and populations in Germany, which illustrate the widespread phenomenon of stress within the society – however, what is stress and what are the effects of stress?

Independent of the cause, stress arises in the individual interaction between the person themselves, their personality and behavior, and the environment the person lives in (Baranowski, Perry & Parcel, 1996). Stress is defined as the individual physiological, mental and cognitive reaction to a perceived stressor that exceeds personal resources (Gerrig & Zimbardo, 2008b; Lazarus, 2012; Lazarus & Folkman, 1986). This means stress occurs through the individual appraisal of a certain situation as a threat (Lazarus & Folkman, 1986). If a situation is appraised as an individual threat, physiological, mental and cognitive reactions to cope with this situation start (Lazarus, 2012), which may have, if the stressor is prolonged, negative effects on the person themselves, their behavior, and the environment. (A detailed definition and description of stress and its development in the person-environment interaction is given in Chapter 3.). And with it, the development of stress-related health complaints, diseases, and illnesses as direct effects of stress. It also leads to a change in the health behavior of the people, their life, and lifestyles (World Health Organization, 2001, 2009).

Since rising stress and the resulting physical, physiological and mental health problems are an issue in all societies around the world (Houtman, Jettinghoff & Cedillo, 2007), the World Health Organization (2010a) declared stress as the most severe health risk of the 21st century.

The link between stress and health

The link between stress and health is well researched. Stress, especially if it is prolonged, may cause a wide range of health complaints, illnesses, and diseases (Rice, 2012). On the one hand, physiological reactions to stress, such as hypertension, inconsistent heart-rate variability, or changes in the hormone system (Cohen, Janicki-Deverts & Miller, 2007) are well researched. On the other hand, individual perceived stress has different mental effects such as depressive symptoms, fatigue, and burnout (Gray-Stanley & Muramatsu, 2011;

Zoer, Ruitenburg, Botje, Frings-Dresen & Sluiter, 2011). The mechanisms may act in a direct way, through direct physiological and mental reactions to stress and related illnesses and diseases, or in a more indirect way, through a change in health behavior (Coon, 2004; Gerrig & Zimbardo, 2008b; Rathus, 2004; Weiten, 2004). (Detailed descriptions of the effects of stress on the person themselves, their health and health behavior, and the environment is given in Chapter 3.)

Besides the enormous effect it has on the health of each individual person, stress is not a problem of each stressed individual alone; stress is a problem which concerns the whole society. Rising stress-related health complaints, illnesses, and diseases, lead to rising direct and indirect health care costs. In 2008 mental and emotional diseases, for which stress is mostly responsible, cost the public health care system 28.7 Billion Euro (DeStatis, 2014). However, this sum represents only direct costs of mental diseases. Indirect costs such as costs of missed workdays due to mental problems or the costs of stress-related diseases such as hypertension, stroke or kidney failures (Janusek, Cooper & Mathews, 2012) have to be added. In 2013, 13.9 % of all sick days (app. 52 million days) of German employees were due to stress-related diseases and individual mental problems (Bundesverband BKK, 2013). Individual perceived stress is one of the most severe cost drivers related to human resource costs in the economy (Bundesverband BKK, 2013), which results in rising costs for a product or service. In combination with rising health care costs, perceived stress and its effects on a person, their health and health behavior is a cofactor for rising personal subsistence expenses (American Psychological Associations Practice Organization, 2010; DeStatis, 10.03.2009; World Health Organization, 2008).

Physical activity in the stress-health relationship

The spotlight on effects of perceived stress on individual health demonstrates that stress has mostly negative effects on a person. The necessity to search for effective variables and strategies that may stop the rising perception of stress and the negative effects is obvious. Physical activity seems to be a potential beneficiary behavioral variable.

In many epidemiologic studies, it is well researched, that physical activity is very beneficial for health. Physical activity is important for the prevention of different non-communicable diseases (Reiner, Niermann, Jekauc & Woll, 2013) and it plays an important role in the therapy of physical and mental health complaints and illnesses(Schulz, Meyer & Langguth, 2011; Siegmund-Schultze, 2009). Overall, physical activity is very beneficial for the overall well-being and a happy life (Norris, Carroll & Cochrane, 1992; Sonnentag, 2001).

If physical activity is beneficial for health, and perceived stress has mostly negative effects on the individual health, then what role can physical activity play in the context of perceived stress and the development of stress-related diseases? Is physical activity able to affect the stress-health relationship, and can it prevent stress related diseases?

Fuchs, Hahn and Schwarzer (1994) developed a framework for describing the effects of physical activity in the stress-health context. Physical Activity is treated as a direct effect on the individual health, a direct effect on the perception of stress and its effects on the person, and as a buffering effect on the stress-health relationship. According to these three possible effects of physical activity on the perception of stress, health outcomes, and the relationship between stress and health; physical activity may also play an important role concerning individual resources, which are important for the appraisal of situations as threats. Physical activity may enhance and guard individual personal resources to withstand stressful situations (Fuchs, Hahn & Schwarzer, 1994). This model, the model of physical activity in the context of individual stress, individual resources, and individual health builds up the framework for this dissertation.

Dissertation outline

The purpose of this dissertation is to research and discuss different roles of physical activity in the context of individually perceived stress and health.

Chapter 2 presents the currently discussed roles of physical activity in the context of individually perceived stress, personal resources, and individual health, according to the outline model of Fuchs, Hahn, and Schwarzer (1994).
The systematic literature review presents long-term effects of physical activity on individual health. Physical activity is a potentially beneficial variable for guarding and enhancing individual health.
Physical activity and individually perceived stress interact in different direct and indirect ways; on the one hand physical activity acts as a moderator variable, buffering the negative effects of perceived stress on individual health.
Here, study 1 researches physical activity as a potential buffering variable in the relationship between individual stress and health complaints in contrast to activities of daily living.
On the other hand, physical activity and individual perceived stress directly interact with each other. This relationship is discussed in both directions, i.e. the effects of physical activity on the individual stress reactivity versus the effects of individual perceived stress on individual physical activity. This dissertation focuses on the second direction, the effects of perceived stress on physical activity.

Chapter 3 locates the development of individual stress in the interaction between the person, their personality and behavior, and the environment in the theoretic framework of Bandura's Social Cognitive Theory (Bandura, 1989b). According to the Social Cognitive Theory, the effects of perceived stress on the person themselves, their behavior, and their environment are briefly reviewed. Study 2 discusses physical activity as a dependent variable of stress and the effects of perceived stress on intra- and inter-individual health behavior. Additionally, study 3 focuses on a day-to-day approach and the individual effects of daily perceived stress on individual daily physical activity.

Chapter 4 completes this dissertation with a general summary and discussion of the found results, its limitations and starting points for further research.

Chapter 2: The role of physical activity – State of the Art

The link between individually perceived stress, individual health and physical activity is researched from different points of view and applying different research disciplines. Fuchs, Hahn and Schwarzer (1994) developed a framework which includes different roles of physical activity in the interactions between individually perceived stress, personal resources, which seems to be the reference point for individual appraisal of stress, and individual health outcomes. The following chapter reviews the discussed effects of physical activity in the context of stress, personal resources, and health.

What role does physical activity play in this relationship?

The framework of Fuchs, Hahn, and Schwarzer (1994) discusses physical activity as a direct and moderating variable in the context of stress, personal resources, and health. In this case, a moderator variable is a personal or environmental element or behavior, which exists before the stressor occurs and which acts boosting, buffering, or lessening on the effect of stress, when stress occurs (Gerber, 2008; Grant, Compas, Thurm, McMahon & Gipson, 2004). This means physical activity is discussed as a direct effect variable on individual stress, personal resources, and individual health, and as a variable affecting the relationship between these three elements.

Figure 1 summarizes the assumed effects of physical activity in the stress-resources-health context: direct effects on the perception of stress, individual resources, and individual health, as well as moderating effects, on the stress ↔ resources and stress ↔ health relationships.

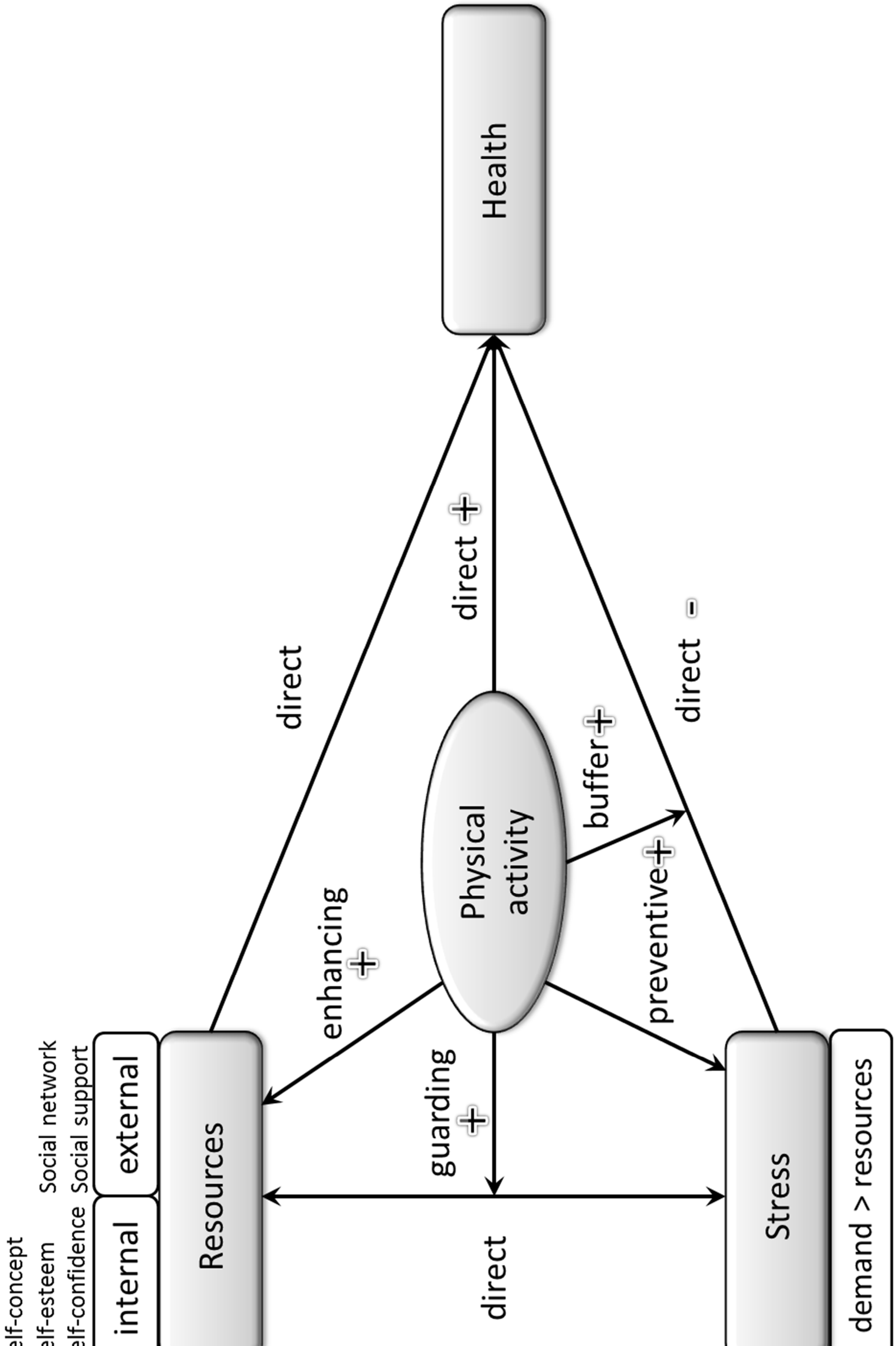

Figure 1: Physical activity in the stress-resources-health context
(Adapted and modified Fuchs, Hahn & Schwarzer, 1994, 2003).

Physical Activity and Health

The first in the model of Fuchs, Hahn, and Schwarzer (1994) represents the relationship between physical activity and individual health (Figure 2). It is discussed as a positive direct effect of physical activity on individual health, which means individual physical activity is beneficial for current and long-term individual health.

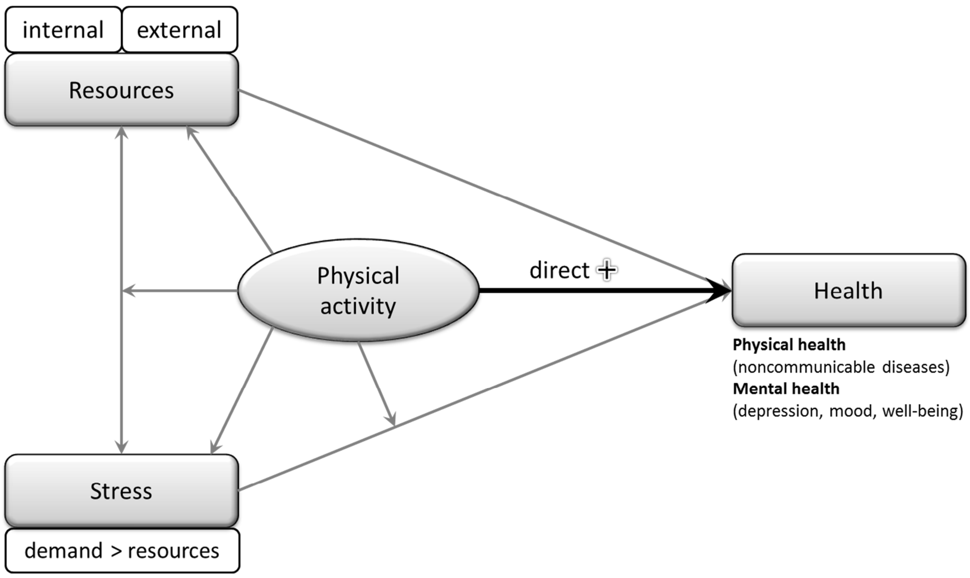

Figure 2: The physical activity-individual health relationship
(Adapted and modified Fuchs, Hahn & Schwarzer, 1994, 2003).

An enormous amount of epidemiologic literature underlines the link between physical activity and individual health (Bouchard et al., 2012; Dishman et al., 2004). Epidemiologic research indicates that especially habitual activity, i.e. routinely practiced physical activity done over years with a minimum of duration, intensity, and frequency per week (Clarke & Janssen, 2013; Dishman et al., 2004; Haskell, 2012), is beneficial for health and necessary to prevent the development of diseases.

However, what is meant by habitual physical activity, and what are the effects of being physically active?

Habitual physical activity refers to a continuously and routinely performed physical activity as part of the daily lifestyle in contrast to actual physical activity which refers to momentary activity or short term activity (Haskell, 2012; Shephard, 2003). In contrast to single sessions of physical activity, i.e. irregular physical activity such as going jogging once, the implementation of regular performed physical activity in the daily routine is necessary to improve the general health (Bouchard et al., 2012; Dishman et al., 2004). To give an overall guideline for health related physical activity, the World Health Organization (2010b) recommends a minimum of 60 minutes for children and adolescents and a minimum of 30 minutes for adults of moderate to vigorous physical activity every day or at least on most days of the week, to achieve beneficial effects for health.

Although “health” is an enormous field of research, general effects of physical activity can be summarized. The following paragraph highlights literature results on the effects of physical activity on selected health risk factors and diseases representing individual physical and mental health. Regarding physical health the effects of physical activity on the development of risk factors such as weight-gain and obesity, and the development of noncommunicable diseases such as coronary heart diseases and type 2 diabetes mellitus are presented. The effects of physical activity on mental health are represented by the effects on individual mood, the development of depression, and general well-being.

Physical health: Risk factors and noncommunicable diseases

Yearly, more than 36 million people die due to noncommunicable diseases such as cardiovascular diseases, cancer, respiratory diseases such as chronic obstructed pulmonary disease and asthma, and type 2 diabetes mellitus (Lim et al., 2012), which represent some of the most severe health risks all over the world (World Health Organization, 2011).

One major risk factor for the development and progression of noncommunicable diseases is unhealthy health behavior, especially physical inactivity, in combination with unhealthy nutrition, smoking, and excessive alcohol consumption. These key elements seem to be responsible for the development and progression of risk factors such as weight-gain and obesity, resulting in the development of noncommunicable diseases (World Health Organization, 2011). However, epidemiologic research demonstrates in a variety of studies that regular habitual physical activity improves the general health and reduces the likelihood of developing risk factors and noncommunicable diseases (Bouchard et al., 2012; Dishman et al., 2004).

The systematic literature review provides an overview of the effects of long-term benefits of physical activity.

Systematic literature review: Long-term health benefits of physical activity – A systematic review of longitudinal studies

Abstract

Background

The treatment of noncommunicable diseases (NCD), like coronary heart disease or type 2 diabetes mellitus, causes rising costs for the health system. Physical activity is supposed to reduce the risk for these diseases. Results of cross-sectional studies showed that physical activity is associated with better health, and that physical activity could prevent the development of these diseases. The purpose of this review is to summarize existing evidence for the long-term (>5 years) relationship between physical activity and weight gain, obesity, coronary heart disease, type 2 diabetes mellitus, Alzheimer's disease and dementia.

Methods

Fifteen longitudinal studies with at least 5-year follow up times and a total of 288,724 subjects (>500 participants in each study), aged between 18 and 85 years, were identified using digital databases. Only studies published in English, about healthy adults at baseline, intentional physical activity and the listed NCDs were included. .

Results

The results of these studies show that physical activity appears to have a positive long-term influence on all selected diseases.

Conclusions

This review revealed a paucity of long-term studies on the relationship between physical activity and the incidence of NCD.

Keywords

Physical activity, adults, weight gain, CHD, Type 2 diabetes mellitus, dementia, NCD

Background

Especially in the last century, most Western countries have experienced significant demographic changes with a continuing increase in the number of older people who face medical and functional challenges, as well as diseases that are age-specific but have often originated in people's younger years (Chan & Woo, 2010; Dishman et al., 2004; Raebel et al., 2004; Schuit, 2006). Most of these diseases including obesity, cardiovascular heart diseases (CHD) or type 2 diabetes mellitus are caused by civilization (Booth & Chakravarthy, 2002; Dishman et al., 2004; Schuit, 2006). The World Health Organization has identified these three diseases as the most severe *noncommunicable diseases* (NCD) causing problems in today's Western world (Chai et al., 2010). Noncommunicable diseases are mostly diseases of slow progression and normally of long duration. The WHO identified for main types of NCDs: cardiovascular diseases, cancer, chronic respiratory diseases and diabetes (World Health Organization, 2011).

Most NCDs primarily result from unhealthy lifestyles including the consumption of too much or unhealthy food (Astrup, Dyerberg, Selleck & Stender, 2008; Chai et al., 2010; Dishman et al., 2004; World Health Organization, 2009), too much alcohol (Dishman et al., 2004; Rehm et al., 2009; World Health Organization, 2009) and excessive smoking habits (Ambrose & Barua, 2004; Dishman et al., 2004; World Health Organization, 2009), combined with physical inactivity (Bijnen, Caspersen & Mosterd, 1994; Dishman et al., 2004; Schuit, 2006; World Health Organization, 2009). More specifically, inactivity and unhealthy eating habits are associated with weight gain, overweight and obesity are the major underlying causes for modern diseases such as CHD or type 2 diabetes mellitus (Berrington de Gonzalez et al., 2010; Vogel et al., 2009). Many cross-sectional and intervention studies have focused on the relationship between an unhealthy lifestyle, e.g. physical inactivity, unhealthy eating behavior, smoking and alcohol consumption, and diseases in different study groups, e.g. high risk groups or different age groups (Vogel et al., 2009). All in all, cross-sectional studies suggest that physical activity may be an important factor for improving the general health and preventing the development of among others the above mentioned NCDs (Dishman et al., 2004). Because NCDs develop, not only by definition, over a long period of time and may have many causes, understanding the development of these diseases and their association with habitual factors such as physical activity is important for developing long-term prevention programs and guidelines. To investigate the development of these diseases, longitudinal studies with healthy persons, i.e. persons without obvious diseases at baseline examination, and a long term epidemiological view are necessary. It is important to follow the general population and not specific subgroups, e.g. high risk groups, persons with indications of NCD (e.g. hypertension or obesity / high body weight) or top athletes, to discover the general progression of the researched complaints in the general population.

Although these diseases are very prominent in many western countries, only few longitudinal studies exist that focus on their development during a person's lifetime and their association with other habitual factors such as physical activity.

Many cross sectional studies have researched the relationship between physical activity and health outcomes - these results are summarized in quite a number of reviews. As opposed to this, only few long-term studies about the effect of physical activity on diseases exist, and to date there are no reviews that concentrate on long-term results in an epidemiologic view.

Therefore, the purpose of this article was to review long-term effects of physical activity on the development of weight gain and obesity, CHD and type 2 diabetes mellitus in healthy adults.

Furthermore, dementia and Alzheimer's disease, two diseases which are of rising importance in modern societies and which develop over a long period of time, are regarded in the context of the long-term influences of physical activity. There is some evidence which indicates that physical activity has a positive effect against the development and progress of these two diseases.

Methods

To determine the importance of physical activity for the above described common health problems (World Health Organization, 2009), only studies investigating the effect of physical activity on *weight gain* and *obesity*, *CHD*, *type 2 diabetes mellitus* and *dementia* and *Alzheimer's disease* were included in this review. We searched the electronic databases Pubmed, BASE and OVID for articles published between January 1980 and May 2012 using the following search terms (without “and” or “or” and with longitudinal as well as long-term as a keyword to reduce the selection to such studies alone): “longitudinal / long-term, physical activity, adult” (3708 articles); “longitudinal / long-term, physical activity, adult, weight gain” (180 articles); “longitudinal / long-term, physical activity, adult, obesity” (483 articles); “longitudinal / long-term, physical activity, adult, CHD / coronary heart disease” (224 articles); “longitudinal / long-term, physical activity, adult, t2dm / type 2 diabetes mellitus” (87 articles); “longitudinal / long-term, physical activity, adult, dementia” (103 articles); and “longitudinal / long-term, physical activity, adult, Alzheimer's disease” (60 articles) (Figure 3 / R1 Selection criteria and number of excluded and included papers / studies.).

From these studies, only *longitudinal studies with five or more years of follow-up time* were included to show the intermediate to long-term effects of physical activity rather than short-term effects of physical activity. In addition, only studies involving adults were included to show the disease development in adulthood and old age. To show the development in the general population, not in subgroups, only large epidemiological studies with *more than 500 participants* were included. Further, only epidemiologic longitudinal studies involving *healthy adult participants* at the baseline examination were included to determine the impact of normal daily activities performed by the general population. Clinical trials, cross-sectional studies, studies involving patients, and reviews and overviews were excluded. Publications using the same study population were included as long as they held more information or investigated other topics as well.

Only those studies were included that referred to *intentional physical activity*, e.g. playing soccer, or intentional activities of daily living, e.g. take the bike for shopping, to determine the impact of leisure time physical activity in the general population. Instead of this, activities of daily living, that are necessary to live a normal self-determined life, e.g. getting up from a chair or climbing stairs, are excluded. Finally only studies published in English were included in this review.

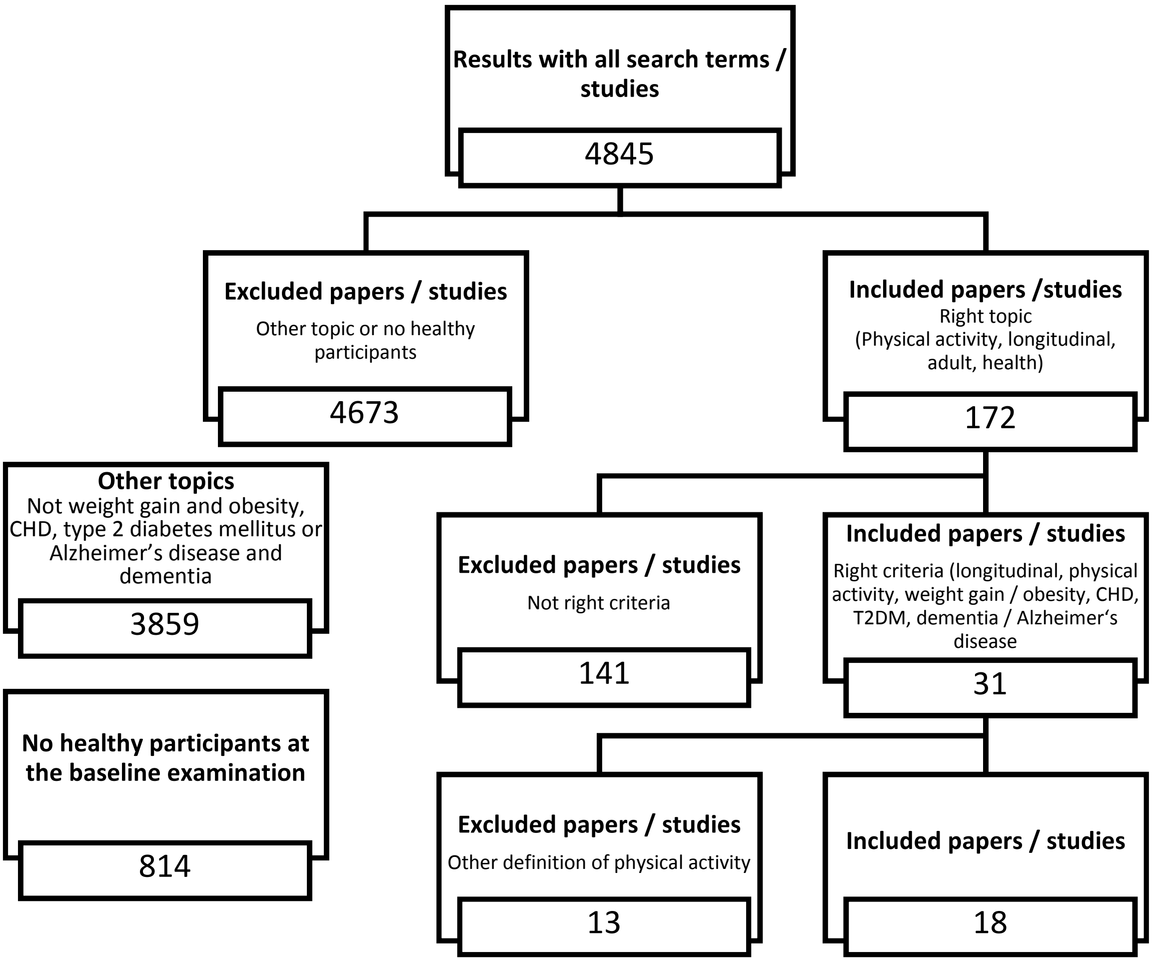

Figure 3 / **R1:** Selection criteria and number of excluded and included papers / studies

Results

Overall, 4,845 articles were identified with our search strategy; of these, 4,827 were excluded from the review (Figure 1) because of the above mentioned reasons. A total of 292,278 subjects were involved at baseline (268,885 subjects at follow-up). Four publications, involving 17,329 subjects, studied the effect of physical activity on weight gain and obesity (Di Pietro, Dziura & Blair, 2004; Gordon-Larsen et al., 2009; Hankinson et al., 2010; Petersen, Schnohr & Sorensen, 2004). Six publications, involving 134,188 subjects, investigated the effect of physical activity on CHD (Donahue, Abbott, Reed & Katshuiko, 1988; Gillum, Mussolino & Ingram, 1996; Kaplan, Strawbridge, Cohen & Hungerford, 1996; Lee & Paffenbarger, 1998; Li et al., 2006; Rodriguez et al., 1994; Sesso, Paffenbarger & Lee, 2000). Five publications, involving 84,647 subjects, studied the effect of physical activity on type 2 diabetes mellitus (Berenzen et al., 2007; Demakakos, Hamer, Stamatakis & Steptoe, 2010; Hu et al., 1999; Katzmarzyk, Craig & Gauvin, 2007; Mozzafarian et al., 2009). Six publications, involving 15,006 subjects, investigated the effect of physical activity on Alzheimer's disease and dementia (Abbott et al., 2004; Chang et al., 2010; Larson et al., 2006; Laurin, Verreault, Linday, MacPerson & Rockwood, 2001; Podewils et al., 2005; Rovio et al., 2005). Some studies included more than one disease accounting for the discrepancy in the overall number of subjects and included studies. The maximum follow-up time ranged from 6 to 60 years.

Effect of Physical Activity on Weight Gain and Obesity

Overall, the studies included in this review showed a negative relationship between physical activity and weight gain or obesity over time. Additional Table 1 summarizes the examination data and the used survey sizes for the included studies on the long-term relationship between physical activity and weight gain and obesity.

An important study analyzing the development of obesity depending on physical activity is the Aerobics Center Longitudinal Study (ACLS) conducted by the Cooper Clinic, Texas (Di Pietro et al., 2004). Between 1970 and 1998, DiPietro et al. (2004) examined 2,501 healthy men aged between 22 and 55 years at baseline and five years later. The daily physical activity level was negatively related to the weight gain during the follow-up time. Those people who reduced their daily physical activity level gained a considerable amount of weight, while those people who maintained the same level of activity during the study did not gain weight. Further, those people who increased their physical activity level during the study experienced weight loss. DiPietro et al (2004) reported that a daily physical activity level with a metabolic rate of at least 60% above the resting metabolic rate is necessary for losing weight. Hence 45 to 60 minutes of brisk walking, gardening or cycling should be included in the daily routine to maintain weight in middle-aged men.

Gordon-Larsen et al (2009) investigated the relationship between walking and weight gain. In the Coronary Artery Risk Development in Young Adults (CARDIA) Study, they examined 4,995 women and men aged between 18 and 30 years at baseline (1985/1986) who were re-examined 2, 5, 7, 10 and 15 years later. After 15 years, there was a negative association between 30 minutes walking per day and weight gain depending on the percentile of baseline weight. Data for people in the 25th percentile of baseline weight showed no significant relation between walking duration and weight gain. In contrast, data for people in the 50th percentile of baseline weight revealed that for every 30 minutes of daily walking the weight gain was 0.15 kg per year less for men and 0.29 kg per year less for women. Finally, data for people in the 75th percentile of baseline weight showed the smallest weight gain: for every 30 minutes of walking per day, men reduced their weight gain by about 0.25 kg per year and women by about 0.53 kg per year without making any other changes to their habitual lifestyle. Hence, the results of this study indicate that participants with a higher baseline weight benefit more from being physically active (for instance, for women: the total weight gain in 15 years was 13 kg for inactive women compared to only 5 kg for active women).

Hankinson et al. (2010) used the same study population (CARDIA) to investigate the physical activity level in relation to a 20-year weight gain. Of 1,561 men and women, those with high habitual activity at the 20-year follow-up had a smaller increase in mean BMI, waist circumference and weight per year compared than those with low habitual activity. Men and women maintaining higher activity gained 2.6 and 6.1 kg less weight over the 20-year period than men and women with low activity, respectively. In addition, the results of that study indicated that women benefit more from maintaining a higher physical activity level than men and that maintaining higher activity levels during adulthood may lessen weight gain during the course of their life.

The Copenhagen City Heart Study by Petersen, Schnohr, and Sorensen (2004) linked cross-sectional and 10 year long-term analyses to determine the development of weight gain. They examined 3,653 women and 2,626 men at three measurement points at 5-year intervals. The participants were aged between 20 and 78 years at baseline. Results of the three cross-sectional examinations (1^{st} at baseline, 2^{nd} after five years, 3^{rd} after 10 years) also showed a negative relationship between physical activity and weight. The preventing effects of medium leisure time physical activity (LTPA) on obesity were lower than those of high LTPA for both genders. The longitudinal analysis revealed a significant direct correlation between the level of LTPA and the risk of becoming obese for men but not for women. In contrast to the results of the cross-sectional analysis, the more active participants had a higher risk of becoming obese. Moreover, the results of that study indicate that obesity may lead to physical inactivity.

Therefore, the results of the first three studies (Di Pietro et al., 2004; Gordon-Larsen et al., 2009; Hankinson et al., 2010) suggest a negative correlation between physical activity and weight gain after several years of follow-up (greater physical activity leads to less weight gain). In contrast, the fourth study (Petersen et al., 2004) provided evidence that being more physically active leads to a greater risk of becoming obese. They suggest that obesity influences the development of physical inactivity; however they did not discuss possible causes and effect relations. These results raise the question of the causality of the relationship between physical activity and weight gain. Detailed information, results and limitations of each study are presented in Table 1 / R1.

Table 1 / R1: Description of studies on the association between physical activity and weight gain / obesity[3]

Criteria	**Study description**
Author / year	**DiPietro et al. 2004**
Study	Aerobics Center Longitudinal Study - ACLS
Baseline measuring point	Baseline between 1970 - 1998 (min. 4 examinations during that time)
Follow up time	5 years
Baseline sample;	216,356 woman-years -735,554 man-years;
Age at Baseline	Age: 20-55 years
Drop out	
Sample in Survey	2501 men
Variables: PA, Outcome	*PA:* 10 specific exercise-related activities within previous 3 months (frequency; duration) Physical Activity Level Energy expenditures (MET) Daily physical activity level *Health Outcome:* Body weight
Results	Daily physical activity level is inversely related to weight gain
Limitations	- results just for men - no common baseline - longitudinal research via person-years and not via overall years - just a subgroup of the basic sample
Author / year	**Petersen et al. 2004**
Study	Copenhagen City Heart Study
Baseline measuring point	Baseline: 1976/78 Follow up measuring points: 1981/83; 1992/93
Follow up time	10 years
Baseline sample;	14 151 men and women;
Age at Baseline	Age: 20 – 78 years
Drop out	1981/83: 11085 men and women; 1992/93: 6542 men and women Overall drop out: 10 498 men and women
Sample in Survey	3,653 women. 2,626 men
Variables: PA, Outcome	*PA:* Questionnaire by Saltin & Grimby: 1. *Physical inactivity*: almost entirely sedentary (reading, TV, cinema) or light physical activity less than 2 h per week 2. *Light physical activity*: 2-4h per week, e.g. walking, cycling, light gardening 3. *Moderate physical activity*: more than 4 h per week or more vigorous activity 2-4 h per week, e.g. brisk walking, fast cycling, heavy gardening, sports where you get sweaty or exhausted 4. *Highly vigorous physical activity*: more than 4 h per

3 The table has been reformatted to fit the dissertation format. The content of the table is nearly unchanged to the published table

	week or regular heavy exercises or competitive sports several times per week *Outcome:* Body weight
Results	Cross-sectional Analyze Odds Ratios (with 95% Confidence Interval) for weight gain in addition to LTPA level

Women	**Men**
1st survey: Low LTPA:1.00 (Ref.) Medium LTPA: 0.70 (0.59-0.83) High LTPA: 0.51 (0.40-0.64)	1st survey: Low LTPA: 1.00 (Ref.) Medium LTPA: 0.71 (0.58-0.85) High LTPA: 0.65 (0.52-0.80)
2nd survey: Low LTPA: 1.00 (Ref.) Medium LTPA: 0.75 (0.63-0.91) High LTPA: 0.58 (0.47-0.72)	2nd survey: Low LTPA: 1.00 (Ref.) Medium LTPA: 0.87 (0.70-1.08) High LTPA: 0.76 (0.61-0.95)
3rd survey: Low LTPA: 1.00 (Ref.) Medium LTPA: 0.61 (0.49-0.76) High LTPA: 0.36 (0.27-0.47)	3rd survey: Low LTPA: 1.00 (Ref.) Medium LTPA: 0.71 (0.54-0.92) High LTPA: 0.52 (0.39-0.68)

Longitudinal Analyze:
Odds ratios (with 95% Confidence Interval) for becoming obese between 2nd and 3rd survey

Women	**Men**
Low LTPA: 1.00 (Ref.) Medium LTPA: 0.93 (0.59-1.45) High LTPA: 1.35 (0.83-2.18)	Low LTPA: 1.00 (Ref.) Medium LTPA: 1.35 (0.73-2.50) High LTPA: 1.93 (1.03-3.60)

Limitation	- high dropout rate
Author / year	**Gordon-Larsen et al. 2009**
Study	Coronary Artery Risk Development in Young Adults - CARDIA
Baseline measuring point	Baseline: 1985/1986 Follow up points: 1987/88 - 1990/91 - 1992/93 - 1995/96 - 2000/01 - 2005/06
Follow up time	20 years
Baseline sample;	5115 men and women - total of 30,690 observations;
Age at Baseline	Age: 18 – 30 years
Drop out	90% - 86% - 81% - 79% - 74%
Sample in Survey	4995 men and women - 23,633 observations
Variables: PA, Outcome	*PA:* Frequency of participation in 13 activity categories (8 vigorous, 5 moderate) over 12 months; exercise units (frequency * intensity)

	Outcome: Body weight measured with a calibrated balance-beam
Results	Inverse association between 30 minutes walking / day and weight gain related to percentile of baseline weight:

Women	Men
25th percentile: β = -0.12 kg/y; p < .01	25th percentile: β = -0.07 kg/y; p = .04
50th percentile: β = -0.29 kg/y; p < .01	50th percentile: β = -0.15 kg/y; p = .03
75th percentile: β = -0.53 kg/y; p < .01	75th percentile: β = -0.25 kg/y; p <.01

	women's total weight gain (15 year): inactive women: +13 kg active women: +5 kg
Limitations	- just walking was added in an energy-index - no other sports are included
Author / year	**Hankinson et al. 2010**
Study	Coronary Artery Risk Development in Young Adults - CARDIA
Baseline measuring point	Baseline: 1985/1986 Follow up points: 1987/88 - 1990/91 - 1992/93 - 1995/96 - 2000/01 - 2005/06
Follow up time	20 years
Baseline sample;	5115 men and women - total of 30,690 observations; Age: 18 – 30 years
Age at Baseline	
Drop out	90% -86% - 81% - 79% - 74%
Sample in Survey	3554 men and women
Variables: PA, Outcome	*PA:* CARDIA Physical Activity History questionnaire *Outcome:* Body weight, bod height, waist circumference
Results	Higher activity level is associated with a smaller increase in mean BMI and weight per year, compared with low activity Mean BMI change / year relative to lower activity category (less than 340 exercise units (men) and less than 192 exercise units (women) (95 CI)

Women	Men
Lower BMI: 1.00 (Ref.)	Lower BMI: 1.00 (Ref.)
Moderate BMI: -.05 (-.16- .05)	Moderate BMI: -.06 (-.11- .00)
Higher BMI: -.13 (-.19 - .07)	Higher BMI: -.05 (-.10 - .03)

	Total less weight gain: Men – high activity: 2.6 kg Women – high activity: 6.1 kg
Limitations	

Note: Description of studies on the association between physical activity and weight gain / obesity; LTPA = Leisure time physical activity

Effect of Physical Activity on Coronary Heart Disease (CHD)

Of all modern diseases, coronary heart disease (CHD) has received the most scientific scrutiny. Overall, most studies reported a negative relationship between physical activity and the occurrence of CHD for physical activity levels above the minimum energy expenditure. Additional Table 2 summarizes the examination data and the used survey sizes of the included studies addressing the longitudinal relationship between physical activity and coronary heart diseases.

In 1948, the National Heart, Lung and Blood Institute founded by Kannel et al. (1986) established the Framingham Heart Study. This research group investigated the general causes and the development of coronary heart disease in 5,209 men and women, aged 30 to 62 years at baseline (Sherman, D'Agostino & Cobb, 1997). The results revealed a negative association between the physical activity level and the emergence of CHD events and overall cardiovascular mortality (Kannel et al., 1986; Kannel & Sorley, 1979; Sherman et al., 1997). Lee and Paffenbarger (1998) compared the results of the Framingham Heart Study with data for 18,835 men who graduated from Harvard University between 1916 and 1950 (Lee & Paffenbarger, 1998) and established the Harvard Alumni Health Study. In five mail-back surveys, researchers investigated the association between physical activity and stroke (Lee & Paffenbarger, 1998) and other CHD (Sesso et al., 2000).

The relationship between energy expenditure and the incidence of stroke showed a u-shape pattern (Lee & Paffenbarger, 1998). Specifically, spending at least 2.000 to 3.000 kcal additional energy per week on physical activity was necessary for reducing the risk of stroke. These results were reassessed for all CHD (Sesso et al., 2000) in 12,516 Harvard Alumni over the course of 16 years (from 1977 through 1996). For CHD in general, the relationship between energy expenditure and the incidence of CHD showed the same u-shape pattern but the curve was shifted towards lower additional energy expenditure: spending at least 1.000 kcal additional energy per week on physical activity was necessary to reduce the risk of CHD. Hence, moderate to vigorous additional physical activity of about 2.000 to 3.000 kcal (min. 1.000 to 2.000 kcal) per week appear to reduce the overall risk for CHD, stroke and other diseases (e.g. hypertension).

Comparable results were also reported by the Honolulu Heart Program (Donahue et al., 1988; Rodriguez et al., 1994) including 8,006 men of Japanese ancestry aged 45 to 68 years at baseline who lived in Oahu, Hawaii. After 16 years, the physical activity reported at baseline was negatively related to CHD events and mortality. However, it is important to note that these results were partially mediated through the effects of hypertension, diabetes mellitus, cholesterol and BMI.

The studies cited in the next section had similar results but also featured the following additional findings.

The Alameda County Health Study by Kaplan et al. (1996) reported the dependency of CHD mortality on several health factors and behavior by quantifying the relative risks of various covariates (age, sex, perceived health, mobility impairment, heart problems, high blood pressure, diabetes mellitus, shortness of breath, current smoking, low BMI and social isolation) in 6928 men and women. After including all covariates, a protective effect of LTPA is still noticeable.

Gillum et al. (1996) investigated the relationship between physical activity and stroke incidence in The National Health and Nutrition Examination Study I Epidemic Follow-Up Study on 5,852 persons aged 24 to 74 years at baseline and reported comparable results as above studies (Donahue et al., 1988; Lee & Paffenbarger, 1998; Rodriguez et al., 1994; Sesso et al., 2000). However, while the u-shaped relationship between physical activity and the incidence of stroke was confirmed for men, for women greater physical activity was negatively linearly associated with the incidence of stroke. In addition, recreational physical activity was not associated with the incidence of stroke in African American subjects, yet a significant interaction between heart rate and the incidence of stroke was observed only for African American subjects. The authors provided limited discussion of these differing results between Caucasian and African Americans.

To investigate the link between obesity and associated diseases, Li et al. (2006) quantified the relative risk of developing CHD dependent on obesity and physical activity. They followed 88,393 Nurses aged 34 to 59 in their Nurses' Health Study from 1980 to 2000. Being overweight and obese was significantly associated with increased risk of CHD. In addition, increased levels of physical activity were related to a graded reduction in CHD risk. Further, greater absolute mass (in kg) gained during adulthood predicted a higher CHD risk. The study concluded that obesity and physical inactivity contribute independently to the development of CHD in women.

Overall, all studies included in this review section showed a predicted negative relation between physical activity and the risk of CHD over time. Two studies (Lee & Paffenbarger, 1998; Sesso et al., 2000) showed that a minimum additional energy expenditure of 1.000 to 2.000 kcal per week is necessary to achieve health related results. Limitations of these studies comprise the inclusion of very specific and selected participants (e.g. Harvard Alumni in the Harvard Alumni Heart Study and Nurses in the Nurses' Health Study). In addition, these results cannot be generalized for the general public because of the selected social and ethnic backgrounds of participants and unbalanced gender distributions. In addition, most studies used Caucasian subjects alone. Hence, additional research on other ethnicities is necessary to obtain generalizable results. Moreover, the summarized studies were not designed to clarify the causality of the relationship between physical activity and CHD events. Additional research on the impact of other lifestyle factors as mediators or moderators of the relationship between physical activity and CHD is necessary. Detailed information, results and limitations of each study are presented in Table 2 / R1

Table 2 / **R1:** Description of studies on the association between physical activity and coronary heart diseases[4]

Criteria	**Study description**
Author / year	**Donahue et al 1988**
Study	Honolulu Heart Program
Baseline measuring point	Baseline: 1965 / 1968 - still continuing as Honolulu - Asia Aging Study Further measuring point: 1977/1979
Follow up time	12 years
Baseline sample;	8 006 men of Japanese ancestry;
Age at Baseline	Age: 45 – 69 years
Drop out	
Sample in Survey	8 006 men of Japan. ancestry
Variables: PA, Outcome	*PA:* Framingham physical activity Index: usual 24 hour physical activity – hours spent in basal, sedentary, slight, moderate and heavy levels of activity *Outcome:* Presence of coronary heart diseases
Results	After 12 years of follow- up results indicate that increased levels of physical activity reported at baseline were inversely related to the risk of coronary heart diseases in both age groups - Relative Risk (with 95% Confidence Interval) of definite heart diseases for active vs. inactive (Ref.) men Age 45-64 years = 0.69 (0.54-0.88) Age 65 and older = 0.42 (0.18-0.96)
Limitations	- no information about sample size / missing / lost persons - results just for men - physical activity only at baseline
Author / year	**Rodriguez et al 1994**
Study	Honolulu Heart Program
Baseline measuring point	Baseline: 1965 / 1968 - still continuing as Honolulu - Asia Aging Study Further measuring point: 1988/1990
Follow up time	23 years
Baseline sample;	8 006 men of Japanese ancestry;
Age at Baseline	Age: 45 – 68 years
Drop out	932 men
Sample in Survey	7 074 men
Variables: PA, Outcome	*PA:* Framingham physical activity Index: usual 24 hour physical activity – hours spent in basal, sedentary, slight, moderate and heavy levels of activity *Outcome:* Presence of coronary heart diseases

[4] The table has been reformatted to fit the dissertation format. The content of the table is nearly unchanged to the published table

Results

Impact of physical activity index on CHD is mediated through its effects on hypertension, diabetes, cholesterol and body mass index.

- Relative risks (with 95% Confidence Interval) for CHD mortality by level of physical activity index among men aged 45-64 years at exam 1 – lowest tertile of physical activity index=Ref.).

	Middle Tertile	Highest Tertile
Age	1.12 (0.88-1.44)	0.74 (0.56-0.97)
Age, Smoking	1.12 (0.88-1.44)	0.72 (0.54-0.94)
Age, alcohol	1.13 (0.88-1.45)	0.74 (0.56-0.98)
Age,hypertension	1.15 (0.90-1.48)	0.77 (0.59-1.02)
Age, cholesterol	1.14 (0.89-1.47)	0.76 (0.58-1.00)
Age, BMI	1.15 (0.90-1.48	0.79 (0.60-1.04)
Age, diabetes	1.17 (0.91-1.50)	0.79(0.60-1.04)

Limitations

- results just for men

Author / year — **Sherman et al. 1994**

Study — Framingham Heart Study

Baseline measuring point — Baseline study: 1948 - biannual follow up actual ongoing
Baseline for this study: 1973

Follow up time — 16 years

Baseline sample; — 5 209 men and women;

Age at Baseline — Age overall study: 30 - 62 years; in this study: 75 years and older

Drop out — 4924 persons

Sample in Survey — 189 women and 96 men

Variables: PA, Outcome — *PA:*
Framingham physical activity Index: usual 24 hour physical activity – hours spent in basal, sedentary, slight, moderate and heavy levels of activity
Outcome:
Death from all causes, incidence of and mortality from cardiac or vascular diseases

Results

women who are more active live longer

- Incidence Rates (with 95% Confidence Interval) for CVD Death within 10 years

Women	Men
Least active: 1.00 (Ref.)	Least active: 1.00(Ref.)
Less active: 0.53 (0.17-1.16)	Less active: 0.73 (0.17-3.12)
Active: 0.40 (013-1.21)	Active: 1.25 (0.28-5.55)
Most active: 0.77 (0.30-1.97)	Most active: 0.52 (0.09-2.94)

Limitations

just participants older than 75 years

Author / year	**Gillum et al. 1996**
Study	The National Health and Nutrition Examination Survey I (NHANES I) Epidemic Follow-up Study
Baseline measuring point	Baseline: 1971/1974 Follow up points: 1982/1984 - 1986 - 1987
Follow up time	16 years
Baseline sample;	7 895 men and women;
Age at Baseline	Age: 45 – 74 years
Drop out	2 043 men and women
Sample in Survey	5 852 men and women
Variables: PA, Outcome	*PA:* Two questions about the habitual physical activity: "Do you get much exercise in things you do for recreation, or hardly any exercise or in between?"; "You're your usual day aside from recreation, are you physically very active, moderately active, or quite inactive?" *Outcome:* Incidence of stroke
Results	Regular physical activity may be beneficial in preventing stroke in women as well as in men. - Age adjusted risks (with 95% Confidence Interval) for stroke incidence associated with recreational physical activity level (high physical activity level = Reference)

Women	**Men**
45 – 64 years Moderate activity: 1.84 (0.53-6.29) Low Activity: 3.37 (1.04-10.98)	*45 – 64 years* Moderate activity: 1.04 (0.55-1.97) Low Activity: 1.22 (0.64-2.33)
Women	**Men**
65 – 74 years Moderate activity: 1.32 (0.79-2.20) Low Activity: 1.68 (1.03-2.73)	*65 – 74 years* Moderate activity: 0.89 (0.60-1.31) Low Activity: 1.43 (0.98-2.08)

Limitations	- self-reported data of stroke without confirming hospital records - only two questions about physical activity to classify the persons

Author / year	**Lee & Paffenbarger 1998**
Study	Harvard Alumni Health Study
Baseline measuring point	Baseline: Mail survey 1977 Mail back 1988
Follow up time	11 years
Baseline sample;	17 835 male graduates from Harvard University between 1916 – 1950;
Age at Baseline	Age: 43 – 88 years
Drop out	6 705 men
Sample in Survey	11,130 male graduates from Harvard University between 1916 and 1950

Variables: PA, Outcome	*PA:* Estimation of daily blocks walks, flights of stairs climbed or to list all sports or recreation in which they had actively participated during the past year. Total energy expenditure, average weekly energy expenditure, kilocalories per week from walking *Outcome:* diagnosis of stroke
Results	Physical activity is associated with decreased risk of stroke in men – u-shaped association Relative risks (with 95% Confidence Interval) of stroke in addition to energy consumption in kcal per week

<1.000 kcal / wk	=	1.00 (Ref.)
1.000-1.999 kcal/wk	=	0.76 (0.59-0.98)
2.000-2.999 kcal/wk	=	0.54 (0.38-0.76)
3.000-3.999 kcal/wk	=	0.78 (0.53-1.15)
>4.000 kcal/wk	=	0.82 (0.58-1.14)

Limitations	- special Subgroup (well-educated, mostly Caucasian) - stroke were ascertained through self-report and death certificates - misclassification - no dietary information available - results just for men

Author / year	**Sesso et al. 2000**
Study	Harvard Alumni Health Study
Baseline measuring point	Baseline: Mail survey 1977 Mail back 1988 or 1993
Follow up time	11 / 16 years
Baseline sample;	17 835 male graduates from Harvard University between 1916 – 1950;
Age at Baseline	Age: 39 – 88 years
Drop out	5 319 men
Sample in Survey	12 516 male graduates from Harvard University between 1916 and 1950
Variables: PA, Outcome	*PA:* Estimation of daily blocks walks, flights of stairs climbed or to list all sports or recreation in which they had actively participated during the past year. Total energy expenditure, average weekly energy expenditure, kilocalories per week from walking *Outcome:* Self-report of CHD
Results	Total physical activity and vigorous activities showed the strongest reductions in CHD risk Relative risks (with 95% Confidence Interval)of CHD in addition to energy expenditure in kJ per week (4.2 kJ = 1 kcal)

<2100 kJ/wk	=	1.00 (Ref.)
2100-4199 kJ/wk	=	0.90 (0.79-1.03)
4200-8399 kJ/wk	=	0.81 (0.71-0.92)
8400-12599 kJ/wk	=	0.80 (0.69-0.93)
>12 600 kJ/wk	=	0.81 (0.71-0.94)

Limitations	- measurement of physical activity may lead to misclassification - no description of activity during the follow- up period - physical activity levels are likely fluctuated - results just for men - special Subgroup (well-educated, mostly Caucasian) - no control of dietary habits
Author / year	**Li et al. 2006**
Study	Nurses' Health Study
Baseline measuring point	Baseline: 1979 - 1980
Follow up time	retrospective questions about weight with age18
Baseline sample;	121 700 female registered nurses;
Age at Baseline	Age: 30 – 55 years
Drop out	33 307 women
Sample in Survey	88 393 women
Variables: PA, Outcome	*PA:* Average number of hours spend each week during the past year on moderate and on vigorous physical activities *Outcome:* Incidence of myocardial infarction (physician)
Results	Association between activity, weight and risk of CHD Hazard Ratios (with 95% Confidence Interval) for weight gain in addition to physical activity level and baseline body weight Sedentary – normal weight: 1.48 (1.24-1.77) Active – obese: 2.48 (1.84-3.34) Sedentary – obese: 3.44 (2.8-4.21)
Limitations	- Retrospective questions about weight with 18 years - Results just for women / Nurses - No assess of cardiorespiratory fitness

Note: Description of studies on the association between physical activity and coronary heart diseases; PA = physical activity; LTPA = Leisure time physical activity; wk= week

Effect of Physical Activity on Type 2 Diabetes Mellitus

While the incidence of type 2 diabetes mellitus in older people has increased rapidly (Dishman et al., 2004), all studies reported a negative relation between physical activity and the risk of type 2 diabetes mellitus. Additional Table 3 / R1 summarize the results of the included studies that investigated the long-term relationship between physical activity and type 2 diabetes mellitus.

In their Nurses' Health Study involving 70,120 nurses aged 40 to 64, which has been on-going since 1976, Hu et al. (1999) investigated the relationship between participants' physical activity level and the development of the relative risks for type 2 diabetes mellitus. Physical activity was negatively related to the incidence of type 2 diabetes mellitus even after adjusting for BMI where participants with higher physical activity levels had a lower relative risk of acquiring type 2 diabetes mellitus than those who with a lower physical activity level.

Berenzen et al. (2007) and Demakakos et al. (2010) reported generally comparable results in 653 men and women in the Copenhagen City Heart Study and in the English Longitudinal Study of Ageing covering different age groups, respectively. In addition to the negative relation between physical activity and the incidence of type 2 diabetes mellitus, Demakakos et al. (2010) showed that moderate to vigorous physical activity (performed at least once per week) is necessary to achieve a positive effect on health and to reduce risk of type 2 diabetes mellitus. Stratifying their results by age revealed that with increasing age a higher intensity per training session or even several sessions per week are required to achieve the same risk reduction.

A high body weight or obesity, often described by the relation between body weight and body height (body mass index—BMI), and socioeconomic status are strong covariates for the relationship between physical activity and the incidence of type 2 diabetes mellitus. For instance, Katzmarzyk et al. (2007) analyzed the association between obesity, physical activity, cardiorespiratory fitness and the incidence of type 2 diabetes mellitus in their Physical Activity Longitudinal Study involving 1.543 men and women. Obesity and physical fitness, but not physical activity, were significant predictors of the incidence of type 2 diabetes mellitus. Mozaffarian et al. (2009) added lifestyle factors in their analysis of the risk of type 2 diabetes mellitus in 4,883 participants of the Cardiovascular Health Study. Low-risk lifestyle factors included physical activity above the median level, dietary score in the upper two quintiles, having never smoked, no alcohol, a body mass index below 25 kg/m^2 and a waist circumference below 88 cm for women or below 92 cm for men. With every healthy lifestyle factor the incidence for type 2 diabetes mellitus decreased by 35%. For people scoring lowest (that is, were the healthiest) in every lifestyle factor, an 82% lower risk for type 2 diabetes mellitus was predicted compared to all other patients. In addition, it was predicted that if these associations was causal, 8 of 10 cases of type 2 diabetes mellitus could be prevented.

All studies (Berenzen et al., 2007; Demakakos et al., 2010; Katzmarzyk et al., 2007; Mozzafarian et al., 2009) reported a negative relationship between physical activity and the incident risk of type 2 diabetes mellitus. However, there are other factors than physical activity that are important in the development of type 2 diabetes mellitus. For instance, the results of the Physical Activity Longitudinal Study by Katzmarzyk et al. (2007) suggest that not only the presence or absence of physical activity is a determining health factor but that the level of obesity and physical fitness also has an influence on the relationship between physical activity and the state of health. However, it is difficult to confirm these conclusions because of the small number of longitudinal studies that consider physical fitness and other lifestyle factors. In addition, the precise mechanism of how physical activity acts to reduce the risk of type 2 diabetes mellitus, such as through altered insulin sensitivity or altered insulin production, is still unknown. Detailed information, results and limitations of each study are presented in Table 3 / R1.

Table 3 / R1: Description of studies on the association between physical activity and type 2 diabetes mellitus[5]

Criteria	Study description
Author / year	**Hu et al 1999**
Study	Nurses' Health Study
Baseline measuring point	Baseline: 1979 Follow up point: 1986
Follow up time	7 years
Baseline sample;	121 700 female registered nurses;
Age at Baseline	Age: 30 – 55 years
Drop out	51 597 women
Sample in Survey	70 103 nurses
Variables: PA, Outcome	*PA:* Average number of hours spend each week with certain activities; Asking about their usual walking speed – weekly energy index was calculated *Outcome:* Diagnosis of diabetes
Results	The physical activity score is inversely associated with the risk of type 2 diabetes mellitus

5 The Table has been reformatted to fit the dissertation format. The content of the table is nearly unchanged to the published table

	Relative Risk (with 95% Confidence Interval) for t2dm in addition to energy expenditure
	1^{st} Quintile = 1.00 (Ref.) 2^{nd} Quintile = 0.77 (0.66–0.90) 3^{rd} Quintile = 0.75 (0.65–0.88) 4^{th} Quintile = 0.80 (0.69-0.93) 5^{th} Quintile = 0.54 (0.45–0.64)
Limitations	- Results just for women - Self-reported answers about diabetes - Just leisure time physical activity – no leisure time physical activity may also be important for diabetes prevention
Author / year	**Berenzen et al 2007**
Study	Copenhagen City Heart Study
Baseline measuring point	Baseline: 1976/1978 Follow up points: 1981/1983 - 1991 - 1998/2000
Follow up time	24 years
Baseline sample;	5 531 men;
Age at Baseline	Median age 19 years
Drop out	4 878 men
Sample in Survey	653 men
Variables: PA, Outcome	*PA:* One question about physical activity habits: inactivity – moderate activity – high activity – very high activity *Outcome:* Diagnosis of diabetes - WHO standardized oral glucose tolerance test
Results	Leisure time physical activity reduces the risk of insulin resistance and impaired glucose tolerance odds ratios (with 95% Confidence Interval) for impaired glucose tolerance in addition to intensity of activity Active = 1.00 (Ref.) Moderate Active = 1.72 (1.09–2.72) Inactive = 4.13 (1.96–8.86)
Limitations	- results just for men - high dropout rate - drop out people are less active and had lightly higher BMI - insulin sensitivity only measured at follow-up - BMI inaccurate measure for body composition
Author / year	**Katzmarzyk et al 2007**
Study	Physical Activity Longitudinal Study
Baseline measuring point	Baseline: 1981 or 1988 Follow up: 2002/2004
Follow up time	16 - 21 years
Baseline sample;	4 900 men and women;
Age at Baseline	Age: 18 - 69 years
Drop out	3 357 men and women
Sample in Survey	1,543 persons - 709 men and 834 women
Variables: PA, Outcome	*PA:* Canadian Aerobic Fitness Test: Maximal Oxygen

	consumption *Outcome:* Self-reported physician diagnosed diabetes
Results	Physical activity, physical fitness and obesity are related to incidence of type 2 diabetes mellitus Odds Ratios (with 95% Confidence Interval) for t2dm in addition to obesity measurements

BMI	=	2.02 (1.63-2.50)
Waist Circumference	=	2.56 (1.93–3.43)
Waist-Hip Ratio	=	3.00 (2.03–4.46)
Skin fold thickness	=	2.14 (1.61-2.85)
Physical activity	=	0.77 (0.58–1.00)
Max. MET	=	0.28 (0.14–0.57)
Physical fitness	=	0.38 (0.23–0.62)

Limitations	- self-reported physician-diagnosed diabetes - high dropout rate
Author / year	**Mozaffarin et al 2009**
Study	Cardiovascular Health Study
Baseline measuring point	Baseline: 1989/ 1990 - 1992/1993 - annual to 1999 – semi-annual by telephone - end 2005
Follow up time	16 years
Baseline sample;	5 888 men and women;
Age at Baseline	Age: 65 years and older
Drop out	1 005 men and women
Sample in Survey	4,883 persons – 34,539 person-years
Variables: PA, Outcome	*PA:* Modified Minnesota Leisure-Time Activities questionnaire: usual walking habits (average pace and distance) *Outcome:* Incidence of diabetes
Results	Lifestyle factors are associated with reduced risk of type 2 diabetes mellitus Hazard Ratios (with 95% Confidence Interval) for t2dm in addition to number of risk factors

2 factors	=	0.54 (0.38-0.76)
3 factors -never smoke	=	0.42 (0.25–0.71)
3 factors -no alcohol use	=	0.32 (0.18–0.55)
4 factors	=	0.18 (0.06–0.56)
5 factors	=	0.11 (0.01–0.76)

Limitations	- limited time points for fasting and post challenge glucose levels - misclassification of diabetes cases - less lifestyle factors as mediator or moderators
Author / year	**Demakakos et al 2010**
Study	English Longitudinal Study of Ageing
Baseline measuring point	Baseline: 1998/2001 Follow up: 2004/2005 – 2006/2007
Follow up time	9 years
Baseline sample;	11 523 men and women;
Age at Baseline	Age: 50 years and older
Drop out	4 057 men and women

Sample in Survey	7 466 men and women
Variables: PA, Outcome	*PA:* How often taking part in three different types of physical activity – vigorous, moderate, low intensity *Outcome:* Incidence of self-reported doctor-diagnosed diabetes
Results	Increasing physical activity intensity decreases the risk of type 2 diabetes mellitus Hazard Ratios (with 95% Confidence Interval) for td2m in addition to intensity of activity No physical activity = 1.00 (Ref.) Low intensity = 0.68 (0.46–1.01) Moderate / vigorous intensity = 0.41 (0.28–0.59)
Limitations	- Results just for people 50 years and older - Use of self-reported physical activity - Self-reported diabetes data

Note: Description of studies on the association between physical activity and type 2 diabetes mellitus; PA = physical activity; LTPA = Leisure time physical activity

Effect of Physical Activity on Alzheimer's Disease and Dementia

The relationship between physical activity and dementia, particularly Alzheimer's disease, is important for the general public because the incidence of dementia increases with increasing age (Dishman et al., 2004). Table 4 / R1 summarize the results of the included longitudinal studies on the relationship between physical activity and Alzheimer's disease and dementia.

The few existing studies (Abbott et al., 2004; Chang et al., 2010; Larson et al., 2006; Laurin et al., 2001; Podewils et al., 2005; Rovio et al., 2005) found that physical activity is negatively related to the incidence of Alzheimer's disease and dementia in healthy men and women. Physically active people are at a lower risk of developing cognitive impairment and have a higher cognitive ability score. Interestingly, activities with low intensity, such as walking, are negatively related to the incidence of dementia and Alzheimer's disease (Abbott et al., 2004). These results indicate that regular physical activity may be an important and potent factor preventing cognitive decline and dementia in healthy older people. Most studies on Alzheimer's disease and dementia originate in the field of Psychology. The link between physical activity and Alzheimer's disease and dementia in healthy participants at baseline has only been reported in very few studies (Abbott et al., 2004; Chang et al., 2010; Larson et al., 2006; Laurin et al., 2001; Podewils et al., 2005; Rovio et al., 2005), further emphasizing the overall lack of studies and specifically the lack of long-term studies that include people without dementia or Alzheimer's disease. Most studies included people who had already been diagnosed with dementia or Alzheimer's disease to research the development of the diseases. Detailed information, results and limitations of all included studies on physical activity and Alzheimer's disease and dementia are presented in additional Table 4 / R1.

Table 4 / R1: Description of studies on the association between physical activity and Alzheimer's disease and dementia[6]

Criteria	Study description
Author / year	**Laurin et al. 2001**
Study	Canadian Study of Health and Aging
Baseline measuring point	Baseline: 1991/1992 Follow up: 1996/1997
Follow up time	5 years
Baseline sample;	9 008 men and women - 6 434 cognitive normal persons;
Age at Baseline	Age: 65 years and older
Drop out	4 393 men and women
Sample in Survey	4 615 men and women
Variables: PA, Outcome	*PA:* Older Americans Research Scale *Outcome:* Modified Mini-Mental State Examination; Neuropsychological test batters
Results	High levels of physical activity are associated with reduced risk Relative Risks (with 95% Confidence Interval) for cognitive impairment, Alzheimer's disease and dementia Cognitive impairment = 0.58 (0.41-0.83) Dementia = 0.63 (0.40-0.98) Alzheimer's Disease = 0.50 (0.28-0.90)
Limitations	- Characterization of physical activity
Author / year	**Abbott et al. 2004**
Study	Honolulu Heart Program
Baseline measuring point	Baseline: 1965 / 1968 - still continuing as Honolulu - Asia Aging Study Follow up: 1994/1996 – 1997/1999
Follow up time	29 – 34 years
Baseline sample;	3 734 men of Japanese ancestry- survivors of the original Honolulu Heart Program cohort;
Age at Baseline	Age: 71-93 years
Drop out	1 477 men
Sample in Survey	2 257 men

6 The Table has been reformatted to fit the dissertation format. The content of the table is nearly unchanged to the published table

Variables: PA, Outcome	*PA:* Average amount of distance walked per day; Physical Activity Index *Outcome:* Cognitive Abilities Screening Instrument; Informant Questionnaire on Cognitive Decline in the Elderly
Results	Estimated relative risk of developing of dementia are associated with the distance walked per day

	Dementia	Alzheimer's disease
>2m/d	Ref.	Ref.
<0.25 m/d	2.12	2.24
0.25-1 m/d	2.06	2.21
1-2 m/d	1.5	1.33

Limitations	- Results just for men - High age participants
Author / year	**Rovio et al 2005**
Study	CADIE - Cardiovascular risk factors Aging and Incidence of Dementia
Baseline measuring point	Baseline: 1972/1977/1982 or 1987 Follow up: 1998
Follow up time	11-26 years
Baseline sample;	2000 men and women;
Age at Baseline	Age: 65-79 years
Drop out	551 men and women
Sample in Survey	900 women 549 men – 1449 participants
Variables: PA, Outcome	*PA:* Questions about the physical activity: "How often do you participate in leisure-time physical activity that lasts at least 20-30 min and causes breathlessness and sweating?" *Outcome:* Incidence of dementia and Alzheimer's Disease
Results	Regular physical activity may reduce the risk or delay the onset of dementia and Alzheimer's disease Odds Ratios (with 95% Confident Interval) for developing dementia and Alzheimer's disease for active people

sedentary	=	Ref.
Dementia	=	0.55 (0.30-1.01)
Alzheimer's Disease	=	0.45 (0.22-0.93)

Limitations	- Categorical ranking of physical activity – no accurate quantify - No changes of physical activity during the follow-up time - No intensity or frequencies of physical activity - Different follow up times
Author / year	**Podewils et al. 2005**
Study	Cardiovascular Health Cognition Study
Baseline measuring point	Baseline: 1992

	Follow up: 2000
Follow up time	8 years
Baseline sample;	5 888 men and women;
Age at Baseline	Age: 65 years and older
Drop out	2 228 men and women
Sample in Survey	3 660 men and women
Variables: PA, Outcome	*PA:* Modified Minnesota Leisure Time Physical Activity questionnaire *Outcome:* Cognitive Status Test, Cognitive Decline in the Elderly Test
Results	Inverse association between physical activity level and incidence of dementia in later life. Hazard Ratios (95%CI) of incident dementia by level of leisure-time energy expenditure

	All-cause dementia	**Alzheimer's disease**
<248 kcal/wk	Ref.	Ref.
248-742 kcal/wk	1.03 (0.81-1..31)	0.99 (0.71-1.38)
743-1,657 kcal/wk	0.81 (0.63-1.05)	0.79 (0.56-1.12)
>1,657 kcal/wk	0.74 (0.57-0.96)	0.64 (0.45-0.93)

Limitations	- High dropout rate - Measurement of physical activity

Author / year	**Larson et al 2006**
Study	Adults Changes in Thought
Baseline measuring point	Baseline: 1994/1996 Follow up: 2000/2002
Follow up time	6 years
Baseline sample;	6 782 men and women in study – Subgroup of 2 581 men and women;
Age at Baseline	Age: 65 years and older
Drop out	841 men and women
Sample in Survey	1 740 men and women
Variables: PA, Outcome	*PA:* Number of days a week the participants did each of presented exercises for at least 15 minutes at a time during the past year *Outcome:* Cognitive Ability Screening Instrument
Results	Regular exercise reduces the risk of dementia Hazard Ratio (with 95% Confidence Interval) for developing dementia: regular activity: 0.62 (0.44-0.86) Incident rate for 1,000 person years 13.0 for >3 times active per week 19.0 for less than 3 times per week
Limitations	- measurement of physical activity

Author / year	**Chang et al. 2010**
Study	AGES – Reykjavik Study – Age, Gene / Environment Susceptibility Reykjavik Study
Baseline measuring point	Baseline: 1967 Follow up: 2002
Follow up time	26 - 35 years
Baseline sample; **Age at Baseline**	5 764 men and women; Born between 1907 – 1935 Age: 37 - 60 years
Drop out	819 men and women
Sample in Survey	2 093 men, 2 852 women overall 4 945 men and women
Variables: PA, Outcome	*PA:* Questions about the biography of physical activity during adult life and how many hours per week physical activity during winter and summer *Outcome:* Digit symbol substitution test, figure comparison, modified Stroop Test California Verbal Learning Test, Digits Backward, CANTAB Spaital Working Memory test
Results	Inverse association between midlife physical activity and cognitive function in later life. Odds Ratios of having dementia among physically active groups compared with none physical active group (95% CI) No physical activity = Ref. <5 h/wk = 0.59 (0.40 – 0.8 >5 h/wk = 0.74 (0.34 – 1.62
Limitations	- Measurement of physical activity - No information about changes in physical activity

Note: Description of studies on the association between physical activity and Alzheimer's disease and dementia; PA = physical activity; LTPA = Leisure time physical activity; wk = week

Discussion

The results of the reviewed studies indicate that physical activity seems to be an important factor that can have beneficial effects for the reviewed noncommunicable diseases weight gain and obesity, CHD and type 2 diabetes mellitus, the risk factors weight gain and obesity and the age-related diseases dementia and Alzheimer's disease.

Two of the three longitudinal studies with at least 5-year follow-up focusing on the development of obesity over time showed a negative relationship between physical activity and obesity (Di Pietro et al., 2004; Gordon-Larsen et al., 2009). Surprisingly, results of one study indicated that high leisure-time physical activity increased the risk of becoming obese in the following ten years for men

(Petersen et al., 2004). The reason for this remains unexplained. Overall, the results of the studies included in this review are inconclusive regarding the required minimum level of physical activity for preventing obesity. There is no evidence for the type, intensity and frequency of activities that lead to positive health results.

Several studies (Donahue et al., 1988; Gillum et al., 1996; Kaplan et al., 1996; Lee & Paffenbarger, 1998; Li et al., 2006; Rodriguez et al., 1994; Sesso et al., 2000; Sherman et al., 1997) investigated the longitudinal effect of physical activity on the development of coronary heart diseases. Overall, the results showed a positive long-term effect where people who were physically active had a lower risk of suffering from a CHD later in their life. A minimum additional 1,000 kcal energy expenditure per week spent on physical activity has been found to be necessary for preventing overall CHD (Sesso et al., 2000). However, information on the type, intensity and frequency of activities necessary for reducing the incidence of CHD are unknown.

The results of studies (Berenzen et al., 2007; Demakakos et al., 2010; Katzmarzyk et al., 2007; Mozzafarian et al., 2009) examining the effect of physical activity on the risk of suffering from type 2 diabetes mellitus showed a negative relation where higher rates of physical activity were associated with a lower risk of developing a type 2 diabetes mellitus. A higher level of physical activity appears to be required, that is a higher intensity per training session or even several sessions per week are needed, for achieving health benefits (Demakakos et al., 2010). Presumably, not only physical activity level but also weight and fitness status, and their association, play a role in the development of type 2 diabetes mellitus (Katzmarzyk et al., 2007).

Finally, six studies (Abbott et al., 2004; Chang et al., 2010; Larson et al., 2006; Laurin et al., 2001; Podewils et al., 2005; Rovio et al., 2005) focused on the relationship between physical activity and the incidence of dementia and Alzheimer's disease. Results of these studies emphasized the importance of regular physical activity, but no information was provided about the type, intensity and frequency of physical activity that has the greatest health benefit.

However, several problems in the reviewed studies have become apparent.

First: There are only few long-term studies on the relationship between physical activity and the incidence of NCD, which stresses the general paucity of longitudinal research in this area. More long-term studies, following the development of diseases and the impact of lifestyle, especially physical activity, are needed. Further longitudinal studies are needed that differentiate between ethnic groups, genders and groups with different social backgrounds. The results presented in this review only encompass the relationship between physical activity and the incidence of NCD in western countries and mainly for Caucasian participants. In addition, only adults were included in these studies, and hence the results cannot be generalized to other groups. Many age related diseases, such as type 2 diabetes mellitus, CHD or certain types of cancer, develop over a long time before they are diagnosed by a physician. To identify this development in detail, longitudinal studies involving healthy participants at baseline should be conducted and these participants should be followed into older age when the disease occurs. To understand this lifelong development of NCD, studies following children throughout their lifespan are desirable. To the best of our knowledge, there are only very few studies that follow children through their adolescence into their adulthood (Juonala et al., 2005; Must, Jaques, Dallai, Bajema & Dietz, 1992). The realization of this approach is very difficult, so the research should be as long as possible and about different groups, e.g. different age-related cohorts.

Second: However, more research is necessary on the clinical picture and the development of NCD. Clearly, a thorough insight into these aspects is a prerequisite for the design and development of effective prevention programs. In addition, the relationship between physical activity and the development of NCD must be better understood including the role of other parameters, such as, for instance, nutrition, body composition, alcohol consumption and smoking behavior. Indeed, results of some of the included studies (Abbott et al., 2004; Chang et al., 2010; Demakakos et al., 2010; Gordon-Larsen et al., 2009; Hankinson et al., 2010; Hu et al., 1999; Kaplan et al., 1996; Larson et al., 2006; Lee & Paffenbarger, 1998; Li et al., 2006; Mozzafarian et al., 2009; Podewils et al., 2005; Rodriguez et al., 1994; Sesso et al., 2000) suggested that other factors including eating behavior and food intake, smoking habits and a general activity level or disease specific risk factors such as hypertension are involved in the correlations of physical activity and health outcomes. It is almost impossible to explain the impact of just one factor, e.g. just physical activity, on the development of a lifestyle related complains like CHD - other factors are always involved, e.g. genetic constitution, other diseases, for instance obesity in the relationship with type 2 diabetes mellitus, personal behavior or individual factors, like cognitive, motivational, volitional or emotional aspects.

Third: Most studies (Abbott et al., 2004; Chang et al., 2010; Demakakos et al., 2010; Di Pietro et al., 2004; Donahue et al., 1988; Gordon-Larsen et al., 2009; Hankinson et al., 2010; Hu et al., 1999; Kaplan et al., 1996; Larson et al., 2006; Laurin et al., 2001; Lee & Paffenbarger, 1998; Li et al., 2006; Mozzafarian et al., 2009; Petersen et al., 2004; Podewils et al., 2005; Rodriguez et al., 1994; Rovio et al., 2005; Sesso et al., 2000; Sherman et al., 1997) only used self-reported/estimated physical activity for measuring participant's physical activity. However, some studies (Katzmarzyk et al., 2007; Sui et al., 2007)(this study was excluded from the review because they researched just physical fitness, not intentional physical activity), showed that the correlation of physical activity and health benefits are mediated through the physical fitness level. The quality and relevance of findings could be improved by the use of an objectively assessed variable, such as the physical fitness level measured by a fitness test or the physical activity level monitored by an accelerometer to become independent of subjective estimates and social desirability (Adams et al., 2005). Another limitation of using self-reported physical activity alone is the fact that most questionnaires only feature the actual physical activity at the time of the examination, and hence are unable to assess physical activity performed between questionnaire administrations. However, this information is critical for determining the importance of continuous physical activity in a healthy and active lifestyle and its benefits for health (Klaperski, Seelig & Fuchs, 2012a; Klein & Becker, 2008).

The reviewed studies have shown that physical activity could help in the prevention of non-communicable and age-related diseases. The studies have shown that it is necessary to include physical activity into prevention programs for NCD and to inform the patients and the population in general about its virtues. To achieve this, a closer cooperation between physicians, research and sport facilities, is needed. Research and physical activity service providers, e.g. gyms or sports clubs, health insurances or public providers (e.g. adult education centers) have to cooperate together to improve the general health. In addition, the knowledge about the causes and the development of modern diseases in the population should be improved. Instead of treating with medicine alone, physicians should advise patients to be more physically active within their limits. Children and adolescents should generally be encouraged to maintain a healthy lifestyle throughout their lives. In addition, public health projects that are targeted at improving the general health during adulthood and older age should focus on effective disease prevention starting during childhood.

It is important to highlight the limitations of this review in order to provide a context for the results. First, the assessment is limited to published work and may be subject to publication bias. Second, the influence of several confounders, as age, the lag between baseline and follow-up, or attrition rate, could affect conclusions of this review. Third, the work contained in this review is limited to English-written journals and thus the results cannot generalize to studies conducted and published in other languages. Forth, we included only studies with more than 500 participants. Fifth, the literature reviewed consisted of self-reported physical activity. Finally, the review is limited to the search terms and data-bases contained in our "Method" section. Studies that have not been abstracted with these key words will be missing from our review.

Conclusions

This review indicates the relative lack of epidemiologic longitudinal studies on the effects of physical activity in addition to non-communicable diseases. The presented studies exclusively illustrate positive results. To the best of our knowledge no other studies reporting no or negative results over time exist.

To show the longitudinal improvements of physical activity in addition to the presented non-communicable diseases of a large number of adults within normal communities, no studies with subsamples or unhealthy participants alone were considered. This review just focuses on studies with more than 500 healthy participants. Other studies (Drygas, Kostka, Jegier & Kuński, 2000) following smaller samples of participants were not included in this review; however they too contribute to the long term understanding of the development of non-communicable diseases.

Overall, the results of the reviewed articles provide a general view about the longitudinal relationship between physical activity and the incidence of NCD and health problems. Physical activity seems to be a relevant factor for preventing age-related diseases; however more long-term research is necessary.

Summarizing the results of the literature review and results of overall literature about the effects of physical activity on individual health, physical activity has positive effects on the development of risk factors such as weight-gain and obesity (Ahn et al., 2012; Ross & Janssen, 2012), and on the morbidity and mortality of noncommunicable diseases such as cardiovascular diseases (Banda et al., 2010; Sesso et al., 2000), type 2 diabetes mellitus (Middelbeek & Goodyear, 2012), and Alzheimer's disease and dementia (Scharpf, Servay & Woll, 2013).

However, the reviewed long-term studies and results of cross-sectional studies, found in a further literature scan, indicate the following requirements in order to achieve this positive effect:

- *Intensity:*
  Overall, results suggest, that a minimum of intensity is necessary for the prevention of risk factors and following noncommunicable diseases (Dishman et al., 2004; LaMonte & Blair, 2012; Swain & Franklin, 2006): To prevent an unhealthy weight-gain or to lose weight, a daily physical activity level with a metabolic rate of at least 60% above the resting metabolic rate is necessary (Di Pietro et al., 2004). Furthermore it was shown, that vigorous leisure time physical activity is more beneficial than moderate leisure time physical activity alone, when trying to prevent weight-gain (Petersen et al., 2004). In contrast to these results, Lee et al. (2014) found that even the lowest quintiles of intensity of runners had a significant lower risk of all-cause mortality compared with no runners.
  Additionally, to reach positive effects through physical activity on the development of coronary heart diseases, a minimum of 1.000 to 2.000 kcal additional energy expenditure per week is necessary; to prevent a stroke, at least 2.000 to 3.000 kcal additional energy expenditure is necessary (Drygas et al., 2000; Kohl, 2001; Lee & Paffenbarger, 1998; Sesso et al., 2000). Demakakos et al. (2010) showed that moderate to vigorous physical activity (performed at least once per week) is necessary to reduce the risk of type 2 diabetes mellitus. Expanding their results by age revealed, that with increasing age a higher intensity per training session or even several sessions per week are required to achieve the same risk reduction.

- *Frequency*:
  In contrast to the required intensity, literature results on the frequency of physical activity sessions are less clear. Lee et al. (2004) analyzed 8.421 men and women in the Harvard Alumni Health Study and found, that “weekend warriors”, this means individuals who pool their physical activity during the weekend, have a 59% lower risk of mortality than inactive individuals. In contrast, Clarke and Janssen (Clarke & Janssen, 2013) found, that infrequently active participants of the Canadian Health Measures Survey (N=2.324 adults) have a 1.73 times higher relative risk for the development of metabolic syndrome than frequently active participants. Lee et al. (2014) demonstrated, that even few sessions per week (1-2 sessions) reduce the risk of all-cause and CVD mortality, even though for CVD mortality three times running per week seems to be most beneficial. Even with these inconsistent literature results, being active seems to improve the general health, even if it is not regularly (LaMonte & Blair, 2012; Lee et al., 2014). However, since the beneficial effect of physical activity on the metabolic system is short-lived, more frequent physical activity sessions may be necessary for a long term prevention of risk factors and the development of noncommunicable diseases (LaMonte & Blair, 2012).
- *Type of physical activity:*
  The presented results support the assumption, that not the physical activity itself, but the energy expenditure through physical activity, indifferent of weather physical exercise or activities of daily living, is responsible for the reduction of risk factors and the reduction of the development of noncommunicable diseases (Blair, LaMonte & Nichaman, 2004). Different studies compared health benefits of physical exercise and activities of daily living, such as gardening, brisk walking while grocery shopping or walking the dog (Arrietta & Russell, 2008; Matthews et al., 2007). This means that the guidelines for improving general health and reducing the risk of the development of noncommunicable diseases do not necessarily have to recommend physical exercise alone; sufficient activities of daily living are beneficial as well (Arrietta & Russell, 2008; Matthews et al., 2007). However, Blair et al. (2004) close their recommendation with the statement that a combination of aerobic, flexibility, and resistance components should

be included in exercises and activities of daily living. Generally spoken, a combination of physical activity exercises and an active daily lifestyle is most beneficial for the prevention of noncommunicable diseases (Blair et al., 2004; LaMonte & Blair, 2012).

- *Physical exercise or physical fitness*:
  Different research results suggest that physical fitness, rather than physical exercise or the overall amount of physical activity, reduces all-cause mortality and the development of noncommunicable diseases (LaMonte & Blair, 2012; Lee et al., 2010). Physically fit persons have a significantly reduced risk of cardiovascular morbidity and mortality (McCartney & Phillips, 2012; Sui et al., 2007; Sui et al., 2010). However, the primary factor for physical fitness is the participation in moderate-to-vigorous-intensity physical activities, which means being physically fit requires sufficient physical activity (Bouchard et al., 2012).

Mental health: Mood, depression and well-being

In addition to the presented literature results of the effect of physical activity on individual physical health, physical activity has positive effects on individual mental health (Asztalos et al., 2009; Kim et al., 2012) and mental and emotional determinants such as the actual mood / affect (Reed & Ones, 2006; Walter et al., 2013), the development of depression (Craike, Coleman & MacMahon, 2010; Dishman et al., 2004; Dugan, Bromberger, Segawa, Avery & Sternfeld, 2014), and the overall individual well-being (Lee & Russell, 2003; Mack et al., 2012; Netz, Wu, Becker & Tennenbaum, 2005; Peeters, van Gellecum, van Uffelen, Burton & Brown, 2014; Penedo & Dahn, 2005; Steptoe & Butler, 1996). However, this dissertation only presents a brief summary of literature results.

Mood:

Individual mood is defined as the actual and short-term emotional state of individuals, in contrast to more long-lasting emotions such as hate, love, pain, or anxiety (Fuchs, 2003).

Different reviews and meta-analyses present the effects of actual and regular physical activity on the individual current mood, especially on positive affects. The results indicate that actual as well as regular physical activity has positive effects on the current mood (Reed & Buck, 2009; Reed & Ones, 2006). Different effect characteristics become obvious in researched literature: a) physical activity affects the positive-activated affect immediately post-exercise; b) physical activity is effective, when the positive-activated affect before the physical activity session is lower than the personal average; c) low- to moderate-intensity exercises seem to have greater effects than higher intensity exercises; d) exercise sessions lasting up to 35 minutes have more effects than longer exercise sessions; e) exercising 3 to 5 times per week might be an optimal training program for improving the individual positive-activated affect (Reed & Buck, 2009; Reed & Ones, 2006).

Depression:

The effect of physical activity on the risk of developing self-reported or diagnosed depression is reviewed in different literature reviews and meta-analyses (Josefsson, Lindwall & Archer, 2014; Mead et al., 2013). The results indicate that physically active individuals report depressive symptoms or are diagnosed with depression less frequently than physically inactive individuals (Mead et al., 2013; Sarris, O'Neil, Coulson, Schweitzer & Berk, 2014). Physical activity may enhance protective personal resources. Additionally, physical activity exercises seem to be a helpful intervention tool for reducing depressive symptoms in patients with mild and moderate depression (Josefsson et al., 2014; Mead et al., 2013; Teychenne, Ball & Salmon, 2008). However, the diagnosis and progress of depression is very individual, resulting in very individual effects of physical activity (Sarris et al., 2014).

Well-being:

Different studies indicate a positive relationship between leisure time physical activity and individual well-being (Caddick & Smith, 2014; Hinkley et al., 2014; Lee & Russell, 2003; Mack et al., 2012; O'Brien et al., 2014; Penedo & Dahn, 2005; Sylvester, Mack, Busseri, Wilson & Beauchamp, 2012).

Apart from positive study results, the mechanisms of the effect of physical activity on individual well-being remain unclear. One important explanation may be that physical activity improves personal resources. Physical activity, for example, improves individual well-being by supporting mental detachment from stressful situations (de Bloom et al., 2010; Sonnentag, 2012; Sonnentag & Bayer, 2005; Sonnentag, Binnewies & Mojza, 2008), in which depleted personal resources can be recharged. With a higher amount of personal resources the individual is able to face situations without feeling challenged or demanded.

This brief summary of the positive effects of regular physical activity on health in general, morbidity and mortality due to different physical and mental diseases demonstrates that physical activity is a potential factor for maintaining and improving physical and mental health.

Different physical and psychological mechanisms for this effect are discussed: On the one hand, physical mechanisms such as direct physiological reactions and physical adaptation (Bouchard et al., 2012; Dishman et al., 2004), and on the other hand psychological mechanisms via an improvement in personal resources through physical activity (Antonovsky, 1979, 1997; Becker, 2001). According to the underlying theoretic framework of Fuchs, Hahn, and Schwarzer (1994), physical activity and individual personal resources are directly interacting and affecting each other.

Physical Activity and Personal Resources

The second focus in the framework of Fuchs, Hahn, and Schwarzer (1994) is on the relationship between physical activity and personal resources (Figure 4).

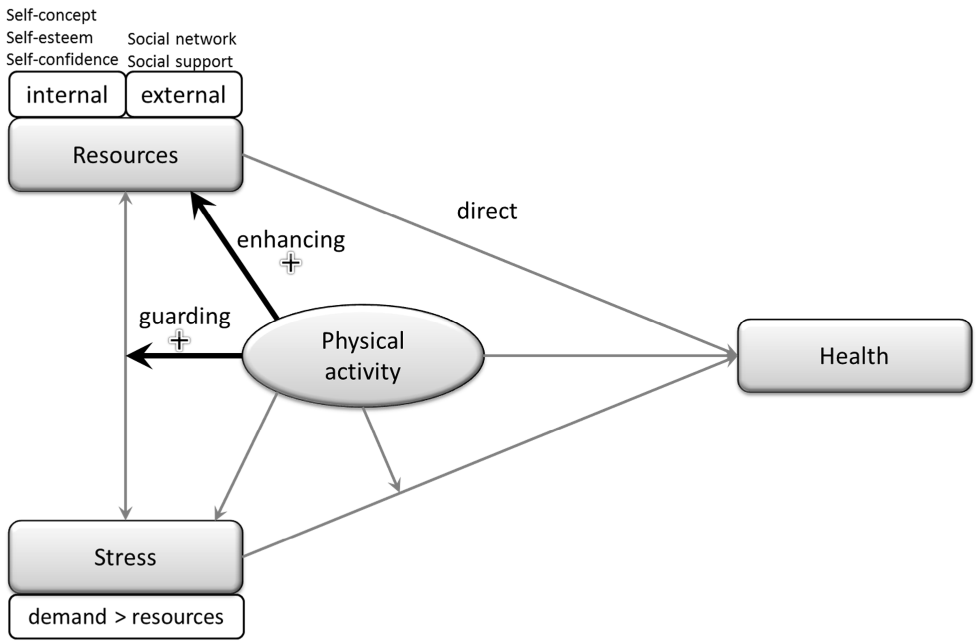

Figure 4: The physical activity-personal resources relationship
(Adapted and modified Fuchs, Hahn & Schwarzer, 1994, 2003).

On the one hand, internal or external personal resources are the individual reference point which defines a situation as stressful. In every challenging situation the person themselves weights their individual resources in contrast to the given demand. The person tries to estimate the amount of required resources to administer to the demanding situation. According to this estimation, the person appraises the situation as challenging or neutral if his or her individual resources exceed the perceived required amount of resources. In contrast, the situation is appraised as threatening or stressful, if the amount of required resources exceed the individual existing resources (Lazarus & Folkman, 1986). A higher amount of more effective personal resources may in consequence increase the level of situation specific demands to be appraised as challenge or neutral. Persons with sufficient personal resources appraise demands as less stressful and therefore may perceive less negative effects of stress (Fuchs et al., 1994). This means, the higher the amount of personal

resources, the more stress the person can cope with without perceiving a significant resource loss and negative health related consequences.
On the other hand, individual resources form the background of individual situation specific behavior and may be very diverse (Hobfoll, 1989, 1998). Overall, Lazarus and Folkman (1986) define individual resources as the available behavior opportunities and objects, personal characteristics, conditions, or energies that enable a person to handle daily life, to behave situation specific, and to adapt to a specific problem (Schröder, 1997). With sufficient personal resources, the person has the possibility to behave normally or situation specific and to maintain a healthy lifestyle (Antonovsky, 1979; Schröder, 1997). The definition shows that individual resources which the person may draw on, are both internal (e.g. self-esteem, self-confidence, or knowledge) and external (e.g. employment, the property of a person, or social support through a social network).

The role of physical activity in enhancing personal resources is researched and discussed in different ways. Especially the personal resources self-esteem, self-efficacy, and self-concept are linked to physical activity. Self-esteem, the value a person places on themselves, not to be mistaken with narcissism or arrogance (Baumeister, Campell, Krueger & Vohs, 2003), and self-efficacy, the individual belief in the person's own ability to complete tasks and reach goals (Coon, 2004), are two fundamental personal resources guiding individual behavior (Bandura, 1977; Baumeister et al., 2003). Physical activity may provide an opportunity to reach personal physical and mental limits evoking a sense of mastery which has positive effects on self-esteem, self-efficacy and the overall self-concept (Crocker, Sabiston & Kowalski, 2006; Sonstroem & Morgan, 1989). Additionally, correlated evidence suggests that physical activity is positively related to the overall self-concept and its sub-elements (Hänsel, 2012; Shavelson, Hubner & Stanton, 1976), social self-concept (Nigg, Norman, Rossi & Benisovich, 2001), emotional self-concept (Crocker et al., 2006) and physical self-concept (Beasley & Garn, 2013; Dishman et al., 2006; Martin & Whalen, 2012; Schneider, Dunton & Cooper, 2008).

Concluding, physical activity enhances individual perceptions of oneself, this means it improves the individual self-concept, gives the opportunity to improve individual limits, and helps in getting into contact with other people, which in turn improves the social self-concept and creates a social network with social support. The person is thereby mentally strengthened, which may lead to improved interactions with the environment and less negative health related effects of stress (Fuchs et al., 1994).

However, it is discussed, that these effects of physical activity on the individual self-concept only become obvious in threatening or stressful situations. This means physical activity may play a part in guarding personal resources in contrast to enhancing personal resources (Fuchs et al., 1994).

Physical activity may guard personal resources by raising the basic level of personal resources and may help weaken the reduction of resources by providing effective coping strategies for handling stressful situations. Effective coping strategies may guard the individual self-efficacy, self-esteem, or self-concept from stress-related damage (Fuchs, 2003; Fuchs et al., 1994).

Physical activity and individual Stress

The third and for this dissertation most important focus in the framework of Fuchs, Hahn, and Schwarzer (1994) is the relationship between physical activity and individually perceived stress (Figure 5).

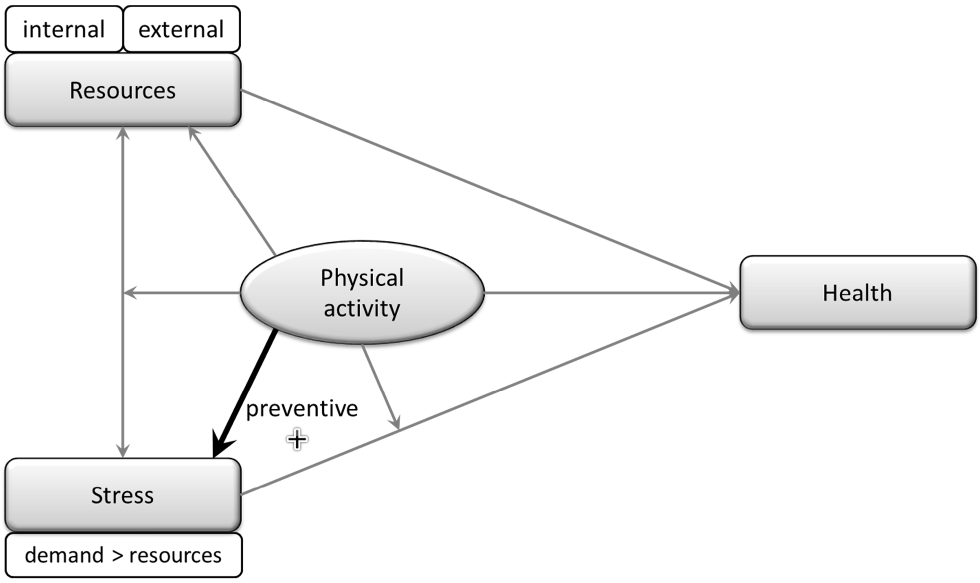

Figure 5: The physical activity-individual stress relationship
(Adapted and modified Fuchs, Hahn & Schwarzer, 1994, 2003).

The presented framework of Fuchs, Hahn, and Schwarzer (1994) discusses different effects of physical activity in the stress-health relationship: a) a direct relationship between physical activity and individual stress, and b) a moderating or buffering effect of physical activity on the effects of individually perceived stress on individual health.

The background of these analyses, the direct relationship and the moderating effect, is a basic relationship between physical activity, the individual perception of stress, and physical activity as described above(Fuchs & Klaperski, 2012).

The focus on the first effect, the relationship between physical activity and individually perceived stress, leads to the question (Figure 6): Does physical activity have effects on the perception of stress; meaning, do physically active people perceive less or more stress? Or contrary to this, does individually perceived stress have effects on physical activity; meaning, do stressed people change, i.e. increase or decreases their physical activity level? (Fuchs & Klaperski, 2012).

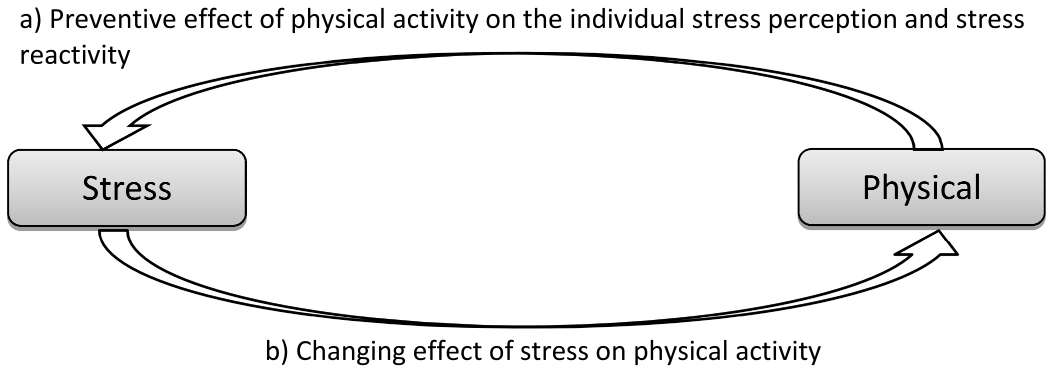

Figure 6: Direct relationship between physical activity and individual perceived stress

The original framework of Fuchs, Hahn, and Schwarzer (1994, 2003) focuses on the first assumption, however, the authors discuss both directions in their research (Fuchs & Klaperski, 2012). The following section summarizes literature results about the relationship between physical activity and stress reactivity. Chapter 3 and the studies 2 and 3 focus on the effect of individually perceived stress on individual physical activity.

Physical activity and stress reactivity

One of the largest US population studies conducted with over 32.000 US citizens researched perceived stress in combination with personal and lifestyle factors such as lifestyle behavior (physical activity and nutrition), socio-demographic variables, and living conditions (Aldana, Sutton, Jacobson & Quirk, 1996). With a relative risk of 0.62, the most physically active group, having an energy expenditure of at least 3.0 kcal/kg/day, reported approximately half as much stress as less active or inactive participants (Aldana et al., 1996). The authors found support for the fact that even moderate amounts of physical activity are related to a significant reduction of perceived stress. Similar results were found by other studies (Craike et al., 2010; Gerber et al., 2014; Gerber, Kellmann, Hartmann & Pühse, 2010; Nguyen-Michel, Unger, Hamilton & Spruijt-Metz, 2006). However, quite a few studies found no effect (Brown & Lawton, 1986; Brown & Siegel, 1988; Kaluza, Keller & Basler, 2001) or even reported an increase in stress when the people tested were physically active (Iwasaki, Zuzanek & Mannell, 2001). Additionally, Gerber et al. (2014) found that only physical activity with vigorous intensity was associated with less stress.

A possible explanation for these inconsistent literature results may be that, compared to the health enhancing effects of physical activity, a minimum of physical activity intensity is necessary to achieve reduced stress reactivity.

However, one main problem of cross-sectional observational studies is the lack of the cause-effect relationship. According to the study design, both variables, stress and physical activity, occur simultaneously. Therefore a direction of the relationship cannot be determined. Longitudinal studies try to overcome this problem via cross-lagged models.

Longitudinal results on the long term effect of physical activity on the perception of stress support the hypothesis, that being physically active reduces the relative risk of suffering from high amounts of stress (Jonsdottir, Rödjer, Habzibajramovis, Börjesson & Ahlborg, 2010; Schnohr, Kristensen, Prescott & Scharling, 2005). For example, Jonsdottir et al. (2010) estimated the relative risks for reporting "high stress" after two years of maintained physical activity for app. 3.000 Swedish health care workers and social insurance officers. When compared to inactive participants, the relative risk for being "highly stressed" decreased with increasing physical activity intensity (inactive: RR =1.0; >2h/week light activity: RR = 0.52; >2h/week moderate to vigorous activity: RR=0.40 (Jonsdottir et al., 2010)). This suggests that physical activity during leisure time may reduce the perception of stress.

In contrast to observational cross-sectional or longitudinal studies, a review of intervention studies may clarify the effects of physical activity. Within an overview on intervention studies concerning the effects of different physical activity programs on the perception of stress in nonclinical settings[7], the following picture for effects emerges (Fuchs & Klaperski, 2012):

- *Inconsistent results:*
  The reviewed studies show inconsistent results: in only 50% of the interventions, effects of physical activity on the perception of stress could be demonstrated; all other studies found no effect or indifferent effects due to the type of the intervention program.
- *Endurance vs. resistance training*:
  Both, studies with an endurance training program and studies with a resistance training program, showed a reduction in the perception of stress; however, no study compared endurance and resistance training effects directly.
- *Frequency, duration, and intensity of the training sessions:*
  The reviewed studies varied with regards to the frequency and duration of training sessions. In all studies with results, a reduction in the perception of stress was achieved; meaning, both the less frequent (2-3 times per week) and more frequent (5-6 times per week) programs reached a reduction in the perception of stress. Concerning the intensity, positive effects have been found for light and moderate intensity training, however, not for high intensity training. Two studies directly compared different training intensities: Norris et al. (1992) found that for moderate training intensity (70-75% of max. heart rate) in adolescents the perception of stress is reduced, however, not for light intensity. In contrast to this, King et al. (King et al., 1993), found a significant decrease of stress for physical activity at 60-73% of the maximum heart rate in 5 training sessions per week, and for physical activity at 73-88% of the maximum heart rate in 3 training session per week.

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7 Inclusion criteria for studies in the review (Fuchs & Klaperski, 2012): a) the physical activity intervention program lasted more than one training week; b) non-clinical setting; c) the study design included a control group (random controlled trial or controlled trial) and d) the dependend variable measures individual perceived stress and not mood or the occurrence of quasi-objective stressors. Studies have been excluded, when the program included other stress reduction techniques, or relaxing physical activities like Yoga, Taiji or Quigong (Fuchs & Klaperski, 2012). Ten studies with the in- and exclusion criteria have been found (Castro, Wilcox, O'Sullivan, Baumann & King, 2002; Eriksen et al., 2002; Gronningæter, Hytten, Skauli, Christensen & Ursin, 1992; King, Taylor & Haskell, 1993; Norris et al., 1992; Norvell & Belles, 1993; Oden, Crouse & Reynolds, 1989; Pavett, Butler, Marcinik & Hodgdon, 1987; Sjögren et al., 2006)

In conclusion , a reduction of stress through moderate intensity activities requires a higher frequency of training sessions (Fuchs & Klaperski, 2012).

- *Interventions in the work context or during leisure time:*
  Five of the reviewed studies are conducted in the work context; however, none of these studies discovered a significant change in the perception of stress. It is conceivable that stress reduction programs during leisure-time are more effective, since most stress occurs due to work demands or conflicts at work. A work related stress reduction program may not reduce stress in the same way due to the lack of detachment form work (Fuchs & Klaperski, 2012). It might even become a further work-related stressor. In contrast, programs with a leisure-time stress reduction approach~~,~~ achieved a significant stress reducing effect.

Summarizing the effects of different intervention studies about the effect of physical activity intervention programs on the perception of stress, results indicate a reduction of perceived stress following a physical activity program. However, the results remain inconsistent and no significant clarity could be reached. More research, especially in different settings, with different activities, intensities, and frequencies is needed to clarify the effects of physical activity.

Physical Activity as a Protective / Buffering Variable

Closely related to the effect of physical activity on individual stress reactivity is the analysis of a potentially moderating or buffering effect of physical activity on the effects of individually perceived stress on individual health outcomes. The model of Fuchs, Hahn, and Schwarzer (1994) presents physical activity not only as a direct effect but also as a moderating variable affecting the effects of stress on individual health (Figure 7) (Gerber et al., 2010; Gerber & Pühse, 2009; Klaperski, Seelig & Fuchs, 2012b; Reiner, Niermann, Krapf & Woll, 2013).

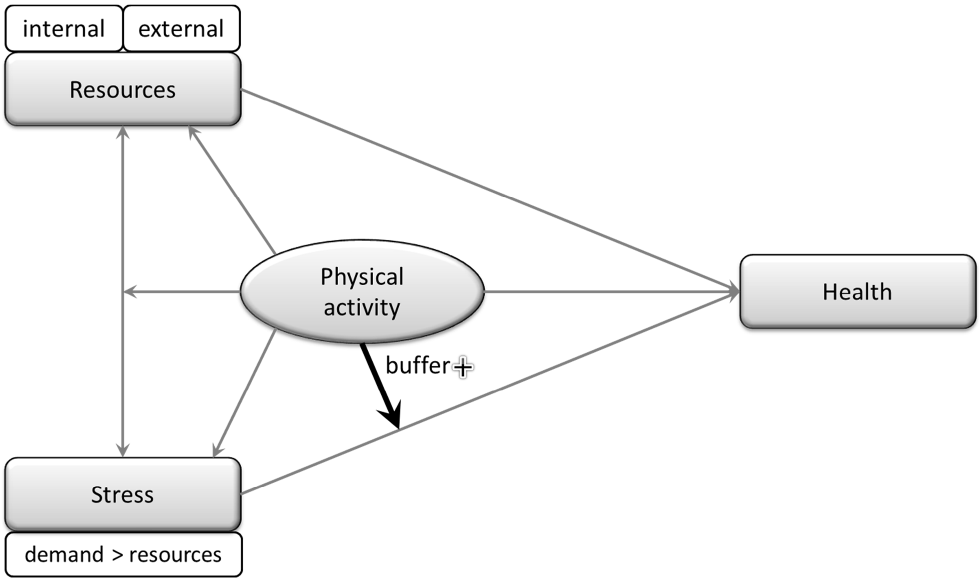

Figure 7: Physical activity as a buffering variable
(Adapted and modified Fuchs, Hahn & Schwarzer, 1994, 2003).

It is assumed that individuals, perceiving high amounts of stress, profit of the health enhancing and protecting effects of physical activity. This means, if the individual perceives stress, physical activity can protect individual health. The buffering effect is the interaction between high amounts of stress and physical activity (Fuchs & Klaperski, 2012; Gerber & Pühse, 2009).

Study 1 researches this buffering effect of physical activity on different health complaints and compares the buffering effect of physical activity with that of activities of daily living.

Study 1: Stress, physical activity, and health complaints

- Buffering effects of physical activity and activities of daily living? -

Abstract

Sport and physical activity are attributed with a positive influence on stress induced complaints due to their overall positive effect on health. The buffering effect on stress has not yet been clearly shown and the findings are inhomogeneous. The following article examines the buffering effect of sport and physical activity on different types of psychological and physical complaints. Therefore, a study was conducted questioning 453 people (M=53.56 years; SD=11.31) about chronic stress (Perceived Stress Scale), physical and psychical complaints (Gießener Beschwerdebogen) and their subjective physical activities (Energy consumption through physical activity - e.g. Soccer or Jogging) and energy consumption - daily bike and walking activity). A buffering effect on nearly all types of complaints could be shown through physical activity, but not through lifestyle activities. Physical activity acts complaint reducing on people suffering from increased stress. A more differentiated examination of the physical activity behavior, the stress perception and the type of complaints might contribute to clearer findings.

Individual perceived stress demonstrably has negative effects for individual health such as hypertension, coronary heart diseases, and mental problems, e.g. depression (Cohen et al., 2007). In contrast, epidemiologic research demonstrates, that physical activity and activities of daily living included in an active lifestyle have positive effects on different health problems and diseases (Dishman et al., 2004). Thus, it stands to reason, that physical activity and activities of daily living might be a prominent way to reduce stress-induced health complaints. However, this effect has not yet been finally proven.

Introduction

Especially in industrial societies, stress seems to be on everyone's mind. (Gerber & Pühse, 2009); hardly any other idiom originally used in research is used as often in daily life as stress. Every age group and all social classes perceive stress. (Haugland, Wold & Torsheim, 2003; Rueggberg, Wrosch & Miller, 2011; Sliwinski, Almeida, Smyth & Stawski, 2009).

It is well known, that individual perceived stress has long-term, chronic, wide-ranging, and mostly negative effects on the individual health (Lochbaum, 2004; Morrison & Bennett, 2009; Ogden, 2007; Steptoe, 2007c). Stress-induced health problems are very diverse and include physical and physiological complaints, such as coronary heart disease or pain, e.g. back pain (Chandola et al., 2007; Lochbaum, 2004; Macleod et al., 2002), as well as mental complaints such as reduced well-being or the development of depressions (Bolger, DeLongis, Kessler & Schilling, 1989; Liu & Alloy, 2010).

In contrast, physical activity and activities of daily living have positive effects on individual health, and may have relieving or preventing effects on the above described diseases (Dishman et al., 2004). Literature supports these assumptions (Dunn, Trivedi & O'Neal, 2001; Lautenschlager et al., 2008; Lee & Paffenbarger, 1998; Sesso et al., 2000).

If physical activity and activities of daily living have positive effects on the individual physical and mental health, the assumption of positive effects of physical activity and activities of daily living in the context of stress related diseases seems to be plausible. The effects of physical activity and activities of daily living may mainly act indirectly as moderators or buffers. A buffer implies that physical activity and activities of daily living lower the negative effects of chronicle stress on individual health (Gerber & Pühse, 2009). Possible mechanisms may be a strengthening and enhancing of personal resources resulting in a higher resistance to stress (Fuchs, 2003, 2007). Especially for persons perceiving high amounts of stress, physical activity and activities of daily living may be a way to protect their health.

This raises the question in how far physical activity and activities of daily living have the potential to guard, strengthen or enhance individual personal resources. Due to the negative effects of stress for personal health, these results may be useful.

However, the theoretical foundation of buffer effects remains incomplete. To explain buffer effects, both the theory of resources following Hobfoll (1989, 1998) or the detachment approach by Sonnentag (Sonnentag, 2012; Sonnentag, Binnewies & Mojza, 2010) seem to be promising. Key elements of both theoretical approaches are personal resources, on which a person can resort to during stressful situations. A situation is appraised as stressful if the demands exceed personal resources or if the loss of resources is grater the ability to cope with.

Buffering effects can be explained on both physiological and mental level. Physical activity and activities of daily living can reduce the individual stress-reactivity and by this the negative health effects of stress. Different studies report a relationship between stress and physical activity, resulting in a reduced reactivity of the sympathetic nervous system, e.g. reduction of blood pressure and heart rate. (Gerber & Pühse, 2009; Klaperski et al., 2013; Rimmele et al., 2009; Taylor, 2000). Acute physical activity seems to have regulatory effects of physiological stress reactions.

Additionally, physical activity and activities of daily living have positive effects on personal resources such as self-concept, self- esteem, or self-efficacy (Brown, 1991; Ensel & Lin, 2004; Rector & Roger, 1997), which in turn have effects on the individual appraisal of situations and the following mental stress reaction.

Furthermore, the time spent with physical activity seems to act as a mental detachment from daily life, which seems to improve and recharge lost resources (Sonnentag, 2012; Sonnentag et al., 2010).

Different studies researched the effects of physical activity according to individual stress. However, the results were neither consistent nor comparable (Gerber & Pühse, 2009; Klaperski et al., 2012b), which complicates the evaluation of the effects on personal resources. Some studies verified buffering effects (Haugland et al., 2003; Kaluza et al., 2001), others could not (Gerber & Pühse, 2008). Additionally, some studies could only prove partially buffering effects (Brown, 1991). Reasons for these inconsistent results could be a different operationalization of the researched variables, such as stress via e.g. life event scales or single item questions, and a lack of differentiation of health outcomes, e.g. physical health, mental health or different diseases. Perhaps physical activity and activities of daily living have different effects on different stress-induced health complaints. Additionally, it is thinkable that age and gender are covariates for the relationship between physical activity, stress and health (Bergdahl & Bergdahl, 2002; Folkman, Lazarus, Pimley & Novacek, 1987; Mroczek & Almeida, 2008; Schulz, Schlotz & Wüst, 2002). These inconsistencies are researched in the following study. As there is a difference between the effects of physical activity and activities of daily living, the following study compares between physical activities, such as jogging, swimming or playing soccer which are explicitly done for personal pleasure, and activities of daily living, such as daily cycling or walking, which are part of the day. Physical activity during leisure time seems to be a part of individual relaxation and detachment. In contrast cycling or walking to work or grocery shopping are necessary activities without mental detachment and less relaxation

The purpose of this study is to research the buffering effect of physical activity and activities of daily living on the relationship between stress and individual health complaints. The following assumptions guide the analysis:

1.) It is assumed that physical activity and activities of daily living have positive effects on the relationship between perceived stress and health complaints. In this case, buffering effects will become obvious. To reveal differences, the study compares between physical activity and activities of daily living. Results of work- and organization psychology studies imply that a detachment of the person from demands, e.g. work demands, is necessary for a stress reducing effect of physical activity (Sonnentag & Bayer, 2005).

2.) Since age and gender are covariates for physical activity, activities of daily living, the perception of stress, and health complaints, it is assumed that age and gender may also have effects on the buffering effect. To cover this, age and gender are controlled in the regression analyzes.

In a first step, overall results for physical activity, activities of daily living, the amount of reported stress, and health complaints are presented in general and according to age and gender. It is assumed that men expend more energy on physical activity than women. Additionally, it is assumed that the energy expenditure drops with higher age (Becker, Klein & Schneider, 2006; Tittlbach, Bös, Jekauc & Dugandzic, 2005). According to perceived stress, it is assumed that with higher age less stress is perceived, especially after the end of the working life. Contrary to physical activity, no gender specific differences are assumed in the perception of stress (Gerber & Pühse, 2009). A lot of studies show an increase of physical and mental health complaints with rising age. Additionally is assumed that women report more health complaints than men (Dishman et al., 2004; Mehrbach & Brähler, 2004).

Method

This study was conducted in the frame of a communal health study. The participants filled out paper-pencil questionnaires to the following subjects: Physical activity and activities of daily living, personal health behavior and health behavior within the family, overall stress, individual health, and personal characteristics such as self- esteem or self-efficacy.

Instruments and study description

Questioned were 210 (46.40%) men and 243 women ($N_{overall}$ = 453) aged 25 to 79 (M = 53.56 years; SD = 11.31; ♂: M = 55.31 years; SD = 11.19; ♀: M = 52.11 years; SD = 11.20).

In a first step the used instruments and their statistical qualities are presented. Due to the assumed age and gender specific differences in the relationship between stress, health complaints, physical activity and activities of daily living, the instruments and study participants are described by age and gender (Table 5/S1).

Instruments

Physical activity and activities of daily living during leisure time:

The *actual physical activity* represents the energy expenditure index in kcal per week of all physical activities, calculated according to the physical exercise, the duration of each exercise lesson and the active weeks per year for each exercise (Ainsworth et al., 1983).

The *actual activities of daily living* (ADL) during leisure time were calculated in the same way as the physical activity, using the energy expenditure of the daily amount of cycling, walking, and daily activities, such as gardening (Ainsworth et al., 1983; Woll, Tittlbach, Schott & Bös, 2004). However, the reasons for cycling and walking (for pleasure during leisure time or for active transport to work) were not taken into consideration.

Perceived stress:

In order to capture the perceived stress, the Perceived Stress Scale (PSS) of Cohen, Karmarck and Mermelstein (1983) was used in a German translation by Büssing et al. (Büssing et al., in preparation). Compared to situation specific stress measurements, such as single item questions to the workload (Klaperski, Seelig & Fuchs, 2012), the PSS uses 10 items as to how unpredictable, uncontrollable and overloaded a person has felt the past four weeks of his life. (Cohen & Williamson, 1988) The sum-score of all ten items measures the chronic stress perception.

The ten item scale has an internal consistency of Cronbach‘s α = 0.83. However, the analyze of selectivity shows for item seven („How often did you feel able to handle troubles in your life during the last month?") a selectivity of $r_{it}<0.30$ (Field, 2009), thus it was removed for the analyze (Büssing et al., in preparation). The remaining nine items of the PSS are analyzed as an overall sum-score with an internal consistency of Cronbach's α = 0.85.

Reported health complaints:

To capture the amount of perceived health complaints the Gießener Beschwerdebogen (GBB) according to Brähler, Hintz and Scheer (2008) was used. The GBB-24 measures 24 different health complaints according to their frequency of occurrence on a scale of 0 to 4 (0 = never, 4 = very often). In contrast to other scales, e.g. the Illness-Checklist or single item questions, this distinction (Subscales: 'fatigue symptoms', 'gastrointestinal complaints', 'limb pains', and 'heart complaints') allows a differentiated analyzes of these types of health complaints.

The advantage of the GBB-24 lies in the fact that it can be used as a one-dimensional scale, which measures the general health complaint perception, or specifically its subscales. One possibility is the distinction between physical health complaints ('limb pains', 'gastrointestinal complaints', and 'heart complaints') and mental complaints ('fatigue symptoms') or a distinction on the basis of the different subscales 'fatigue symptoms', 'gastrointestinal complaints', 'limb pains', and 'heart complaints'.

All subscales have a sufficiently good internal consistency (fatigue symptoms: Cronbach's α = 0.85, limb pains: Cronbach's α = 0.75, gastrointestinal complaints: Cronbach's α = 0.74, heart complaints: Cronbach's α = 0.73). As part of the subscale 'gastrointestinal complaints' the item ‚vomit' did not have a sufficiently high enough selectivity (r_{it}= 0,23), thus it was excluded from the following analyzes (Cronbach's α = 0.77 after excluding the item). This led to 23 items of the GBB-24 being analyzed as an overall score of health complaints and the subscales 'fatigue symptoms', 'gastrointestinal complaints', 'limb pains', and 'heart complaints'.

Sample Description:

As an overview of the sample, all used variables are descriptively described. In addition to mean values (M) and standard deviations (SD), ANOVAs and t-tests were used.

Physical activity and activities of daily living

Overall, 76.20% of the men and 81.10% of the women answered the question about their actual physical activity. 'Being physical active' represents participants, who gave information about the type, the duration, and amount of weeks per year of their physical exercise. In contrast 'Being physical inactive' represents participants, who gave no information about their physical exercises or who declared not to be active at all.

Men expend slightly more energy with physical activity and significantly more energy in kcal per week with activities of daily living than women ($♂_{\text{physical activity}}$: M = 638.23; SD = 656.96; $♂_{\text{activities of daily living}}$: M = 684.18; SD = 763.41; $♀_{\text{physical activity}}$: M = 589.46; SD = 609.87; $♀_{\text{activities of daily living}}$: M = 403.07; SD = 573.53 – ANOVA: Physical activity: $F_{(1,442)}$ = 0.65, n.sig.; Activities of daily living: $F_{(1,452)}$ = 19.93, $p < .01$, $\eta^2 = 0.04$).

Divided by the mean age for retirement (men: 63.7 years; women 63.2 years (Deutsche Rentenversicherung, 2012)) the analyzes show, that older participants (>63 years: 30.0% of the men and 20.6% of the women) expend only slightly less energy with physical activity compared to younger participants. In contrast, older participants (men and women) tend to expend more energy with activities of daily living compared to younger participants; however, the differences are insignificant (ANOVA: Physical activity: $F_{(1,442)} = 0.55$, n.sig., Activities of daily living: $F_{(1,452)} = 3.35$, n.sig.). No interaction effects of gender and age group are obvious (ANOVA: Physical activity: gender*age: $F_{(1,442)} = 0.12$, n.sig.; Activities of daily living: gender*age: $F_{(1, 452)} = 0.14$, p = n.sig.). Compared to other studies, these results show no reduction of physical activity or energy expenditure in older age groups (Becker et al., 2006; Woll, 1997).

Perceived Stress

Women report significantly more stress than men ($♀_{Stress}$: M = 14.69; SD = 5.65; $♂_{Stress}$: M = 13.41; SD = 5.77, t = 2.33, df = 435, p = .02, d = .22). Additionally, older men report significantly less stress than younger men ($♂_{>63y}$: M = 11.97; SD = 4.99; $♂_{<63y}$: M = 14.01; SD = 5.98; t = 2.33, df = 203, p = .02, d = .36). In contrast, the perception of stress in women differs only marginally between the age groups ($♀_{>63y}$: M = 13.89; SD = 4.31; $♀_{<63y}$: M = 14.88; SD = 5.91). The analyzes of variance indicate main effects of age and gender, however, no significant interaction between the two (ANOVA: Gender: $F_{(1,435)} = 4.19$, p = .04, $\eta^2 = .01$; Age: $F_{(48,435)} = 7.01$, p < .01, $\eta^2 = .02$; Gender*Age: $F_{(1,435)} = .023$, n.sig.). Both men and women report high amounts of stress and show no significant reduction with higher ages. Compared to the age and gender specific reference values of the scale (Cohen & Williamson, 1988), the participants of this study report, even after the removal of an item, significantly more stress than the reference group (Study: M = 14.09; SD = 5.74; Reference group: M = 12.57; SD = 0.44; t = 5.54, df = 436, p <.01) However, the reference sample dates from 1988 and refers to the American people, which could explain this difference.

Perceived health complaints

Women report higher amounts of health complaints than men in the overall score of health complaints as well as in most subscales (Overall score of health complaints: ♀: M = 21.29; SD = 11.34; ♂: M = 18.92; SD = 11.42; t = -2.03, df = 381, p = .04, d = .21; physical complaints: ♀: M = 14.94; SD = 8.64; ♂: M = 13.65; SD = 8.12; t = -1.52, df = 394, p = n.sig.; mental complaints / fatigue symptoms: ♀: M = 6.50; SD = 3.82; ♂: M = 5.29; SD = 4.33; t = -3.04, df = 419, p < .01, d = .3; gastrointestinal complaints: ♀: M = 3.71; SD = 3.11; ♂: M = 3.74; SD = 3.19; t = .11, df = 416, n.sig.; limb pains: ♀: M = 8.49; SD = 4.46; ♂: M = 7.36; SD = 4.05; t = -2.69, df = 420, p < .01, d = .26; heart complaints: ♀: M. = 3.00; SD = 2.87; ♂: M = 2.55; SD = 2.75; t = -1.66, df = 417, n.sig.). Concerning age, no overall trend is visible. Older men (>63 years) report more problems than younger men in most types of health complaints (overall score of health complaints: ♂$_{<63y}$: M = 18.64; SD = 11.57; ♂$_{>63y}$: M = 19.61; SD = 11.13; physical complaints: ♂$_{<63y}$: M = 13.40; SD = 8.13; ♂$_{>63.}$: M = 14.30; SD = 8.12; mental complaints / fatigue symptoms: ♂$_{<63y}$: M = 5.36; SD = 4.42; ♂$_{>63y}$: M = 5.13; SD = 4.13; gastrointestinal complaints: ♂$_{<63y}$: M = 3.76; SD = 3.06; ♂$_{>63y}$: M = 3.71; SD = 3.51; Limb pains: ♂$_{<63y}$: M = 7.17; SD = 3.96; ♂$_{>63y}$: M = 7.84; SD = 4.24; heart complaints: ♂$_{<63y}$: M = 2.37; SD = 2.68; ♂$_{>63y}$: M = 3.02; SD = 2.92). In women, the opposite occurs, this means older women report less problems than younger women for all health complaints, with the exception of heart complaints (overall score of health complaints: ♀$_{<63y}$: M = 21.57; SD = 11.47; ♀$_{>63y}$: M = 19.71; SD = 10.58; physical complaints: ♀$_{<63y}$: M = 15.05; SD = 8.79; ♀$_{>63y}$: M = 14.34; SD = 7.91; mental complaints / fatigue symptoms: ♀$_{<63y}$: M = 6.59; SD = 3.73; ♀$_{>63y}$: M = 6.05; SD = 4.20; gastrointestinal complaints: ♀$_{<63y}$: M = 3.76; SD = 3.12; ♀$_{>63y}$: M = 3.42; SD = 3.07; limb pains: ♀$_{<63y}$: M = 8.51; SD = 4.57; ♀$_{>63y}$: M = 8.39; SD = 3.87; heart complaints: ♀$_{<63y}$: M = 2.92; SD = 2.78; ♀$_{>63y}$: M = 3.38; SD = 3.29). For men and women, these differences between older and younger participants are not significant.

The analyze of variance shows neither a significant main effect for age nor for gender; the interaction term (gender*age) is also not significant for all types of health complaints So the fact that with rising age the perception of health complaints increases cannot be assumed per se.

The comparison with the German reference sample was not done, as the underlying samples differ significantly in age (reference group: 18-60 years; study sample: 25-79 years) and one item was removed. Table 5 / S1 shows the presented descriptive results in detail.

Analytic Model

The following analysis presents hierarchic regression models using z-standardized values. In the first step, the models only include main effects of stress and physical activity / activities of daily living (Table 5 /S1). In order to express the assumed buffering effect, the interaction terms of stress*physical activity and stress*activities of daily living are included in the basic model in a second step (Table 6 / S1). SPSS 20 was used for the analysis. The significance level is 5%.

Table 5 / **S1:** Study description; overall and by gender

		Overall sample			**Men**			**Women**		
		N	**M**	**SD**	**N**	**M**	**SD**	**N**	**M**	**SD**
Age										
	overall	453	53.56	11.31	210	55.31	11.19	243	52.11	11.20
Energy expenditure due to physical activity										
	overall	453	612.20	632.00	206	638.23	656.96	236	589.46	609.87
	<63 years[1]	336	621.73	633.16	145	661.22	652.36	190	594.87	618.35
	≥63 years[1]	107	576.53	629.87	61	583.60	670.02	46	567.15	579.50
Energy expenditure due to activities of daily living										
	overall	453	533.39	682.12	210	684.18	763.41	243	403.07	573.53
	<63 years[1]	341	489.86	672.30	147	635.86	773.84	193	381.20	561.77
	≥63 years[1]	113	660.01	697.35	63	796.92	732.13	50	487.50	615.51
Stress										
	overall	437	14.09	5.74	205	13.41	5.77	232	14.69	5.65
	<63 years[1]	333	14.50	5.95	145	14.01	5.98	188	14.88	5.91
	≥63 years[1]	104	12.78	4.79	60	11.97	4.99	44	13.89	4.31
Health complaints										
Overall score	overall	383	20.18	11.42	179	18.92	11.42	204	21.29	11.34
	<63 years[1]	301	20.33	11.59	128	18.64	11.57	173	21.57	11.47
	≥63 years[1]	82	19.65	10.86	51	19.61	11.13	31	19.71	10.58
Physical complaints	overall	396	14.33	8.41	187	13.65	8.12	209	14.94	8.64
	<63 years[1]	311	14.34	8.54	134	13.40	8.13	177	15.05	8.79
	≥63 years[1]	85	14.32	7.99	53	14.30	8.12	32	14.34	7.91
Mental complaints	overall	418	5.94	4.10	194	5.29	4.33	224	6.50	3.82
	<63 years[1]	323	6.07	4.08	138	5.36	4.42	185	6.59	3.73
	≥63 years[1]	95	5.51	4.17	56	5.13	4.13	39	6.05	4.20
Fatigue symptoms	overall	418	5.94	4.10	194	5.29	4.33	224	6.50	3.82
	<63 years[1]	323	6.07	4.08	138	5.36	4.42	185	6.59	3.73
	≥63 years[1]	95	5.51	4.17	56	5.13	4.13	39	6.05	4.20
Gastro-intestinal complaints	overall	418	3.72	3.14	197	3.74	3.19	221	3.71	3.11
	<63 years[1]	324	3.76	3.09	139	3.76	3.06	185	3.76	3.12
	≥63 years[1]	94	3.60	3.34	58	3.71	3.51	36	3.42	3.07
Limb pains	overall	422	7.96	4.30	198	7.36	4.05	224	8.49	4.46
	<63 years[1]	329	7.93	4.37	141	7.17	3.96	188	8.51	4.57
	≥63 years[1]	93	8.05	4.09	57	7.84	4.24	36	8.39	3.87

Heart complaints	overall	419	2.79	2.82	196	2.55	2.75	223	3.00	2.87
	<63 years[1]	326	2.68	2.74	142	2.37	2.68	184	2.92	2.78
	≥63 years[1]	93	3.17	3.07	54	3.02	2.92	39	3.38	3.29

Note: Description of the variables: Age, Energy expenditure due to physical activity, Energy expenditure due to activities of daily living, Stress, Health complaints (Overall score of health complaints, physical complaints, mental complaints, fatigue symptoms, gastrointestinal complaints, limb pains, heart complaints), Presented are N, mean (M), and standard deviation (SD) for the overall sample and separated by gender; [1]The separation at 63 years is due to the mean starting age for retirement of 63.78 years for men and 63.24 years for women (Deutsche Rentenkasse, 2012)

Results

The results of the relationship between perceived stress, reported health complaints, physical activity, and activities of daily living are presented in the next paragraph. Due to the fact, that some variables assume an effect of age and gender, the regression models for buffering effects are controlled for age and gender. In a first step, the relationships between stress (predictor) and health complaints (criterion) as well as between physical activity / activities of daily living (moderator variables) and health complaints (criterion) are analyzed. The analysis of buffering effects requires significant relationships between the analyzed variables.

As assumed, perceived stress is associated with the amount of perceived health complaints, this means, the more stress a person perceives, the more health complains he reports ($r = .37$, $p < .01$). Additionally the assumed negative relationship between the energy expenditure due to physical activity and reported health complaints becomes apparent ($r = -.16$, $p < .01$). High amounts of energy expenditure due to physical activity are related with fewer reports of health complaints. Compared to these results, the amount of reported health complaints is not related with the energy expenditure due to activities of daily living ($r = .06$, p = n.sig.).

Buffering effects of physical activity and activities of daily living

The analyses of potential buffering effects are calculated using moderator analyses with hierarchical regression models. Thereby in a first step the individual perception of health complaints is included as the dependent variable (‘overall score of health complaints’) and in a second step is separated into the given subscales (‘fatigue symptoms‘, ‘gastrointestinal complaints‘, ‘limb pains‘, and 'heart complaints'). In order to clarify the variance gains (R^2), a hierarchical regression model without (Table 6 /S1) and with interaction term (Table 7 / S1) was used (Gerber & Pühse, 2009).

In a first step the main effects of stress and physical activity /activities of daily living are presented. A further differentiation between age and gender follows. Table 6 / S1 presents the relationships between stress and physical activity /activities of daily living and the various types of health complaints. Table 7 /S1 presents the relationships between stress and physical activity / activities of daily living and the related interaction terms (stress*physical activity and stress*activities of daily living) and the various types of health complaints.

Table 6 / S1: Results of the linear regression models: stress, physical activity (PA) / activities of daily living (ADL) on various health complaints

Activity		Main effects		Overall model				
		Stress	**Activity**	**R^2**	**F**	**df**	**n**	**p**
Overall score of health complaints[a]	PA	.36**	-.14**	.15	33.65	2	373	<.01
	ADL	.38**	.08	.14	31.35	2	376	<.01
Physical complaints[b]	PA	.31**	-.14**	.12	26.55	2	386	<.01
	ADL	.33**	.09	.11	24.05	2	389	<.01
Mental complaints[b]	PA	.36**	-.13**	.15	31.52	2	397	<.01
	ADL	.38**	.03	.14	32.75	2	404	<.01
Fatigue symptoms[a]	PA	.36**	-.13**	.15	31.52	2	397	<.01
	ADL	.38**	.03	.14	32.75	2	404	<.01
Gastrointestinal complaints[a]	PA	.26**	-.09*	.08	17.58	2	400	<.01
	ADL	.27**	.02	.07	15.87	2	405	<.01
Limb pains[a]	PA	.24**	-.17**	.09	20.81	2	407	<.01
	ADL	.27**	.10*	.07	17.28	2	411	<.01
Heart complaints[a]	PA	.28**	-.06	.08	18.45	2	401	<.01
	ADL	.29**	.13**	.09	21.99	2	407	<.01

Note: Results of the regression analyses: B-Coefficient and significance of main effects of stress, physical activity (PA), and activities of daily living (ADL), characteristics of the overall model; z-standardized variables; significance level: $p \le .01$ (**), $p \le .5$ (*); [a] All dependent variables (types of health complaints) are sum scores of different single items representing that health complaint (Brähler et al. 2008); [b] Calculation of categories by combining the subscales: physical complaints: Gastrointestinal complaints, limb pains, and heart complaints; mental complaints = fatigue symptoms

Table 7 / **S1:** Results of the linear regression models: stress, physical activity (PA) / activities of daily living (ADL), and the interaction terms (stress*PA; stress*ADL) on various health complaints

Activity		Main effects		Interaction	Overall model				
		Stress	Activity	Stress x Activity	R^2	F	df	n	p
overall score of health complaints[a]	PA	.37**	-.15**	-.12**	.16	25.1	3	373	<.01
	ADL	.38**	.08	-.02	.14	20.85	3	376	<.01
Physical complaints[b]	PA	.32**	-.15**	-.11*	.13	19.86	3	386	<.01
	ADL	.33**	.09	.01	.12	16.30	3	389	<.01
Mental complaints[b]	PA	.37**	-.14**	-.10*	.16	22.46	3	397	<.01
	ADL	.37**	.03	-.06	.14	22.37	3	404	<.01
Fatigue symptoms[a]	PA	.37**	-.14**	-.10*	.16	22.46	3	397	<.01
	ADL	.37**	.03	-.06	.14	22.37	3	404	<.01
Gastrointestinal complaints[a]	PA	.26**	-.10*	-.03	.08	11.85	3	400	<.01
	ADL	.27**	.02	.03	.07	10.66	3	405	<.01
Limb pains[a]	PA	.26**	-.18**	-.17**	.11	18.00	3	407	<.01
	ADL	.26**	.10*	-.03	.07	11.65	3	411	<.01
Heart complaints[a]	PA	.28**	-.07	-.06	.08	12.80	3	401	<.01
	ADL	.29**	.13**	-.01	.09	14.63	3	407	<.01

Note: Results of the regression analyses: B-Coefficient and significance of main effects and interaction terms of stress, physical activity (PA), and activities of daily living (ADL), characteristics of the overall model z-standardized variables; significance level: p ≤ .01 (**), p ≤ .5 (*)

[a] All dependent variables (types of health complaints) are sum scores of different single items representing that health complaint (Brähler et al. 2008); [b] Calculation of categories by combining the subscales: physical complaints: Gastrointestinal complaints, limb pains, and heart complaints; mental complaints = fatigue symptoms

All linear regression models show significantly positive regression coefficients for perceived stress on each type of health complaints. Higher perceived stress goes along with a higher amount of reported health complaints.

Concerning the second main effect variable (activity) on the various health complaints, a differentiated picture emerges: On the one hand, physical activity has lower main effects; on the other hand, these main effects are not significant for all researched health complaints. Physical activity has the assumed negative relationships with the overall score of health complaints, physical, and mental complaints, as well as the subscales fatigue symptoms and limb pains. Participants who spent more energy due to physical activity reported less health complaints. In contrast to this, no significant relationship exists for gastrointestinal complaints. In contrast to other literature results, physical activity also has no effect on heart complaints (Dishman et al., 2004; Lee & Paffenbarger, 1998; Sesso et al., 2000).

The second variable, activities of daily living, offers a different picture (Table 6 / S1), it shows none of the assumed relationships with the analyzed health complaints. Energy spent with activities of daily living does not lead to a reduction of health complaints. This means, for participants, who spend most of their energy with activities of daily living and not with physical activity, no activity-induced health improvements arise.

The inclusion of the interaction terms (stress*physical activity and stress*activities of daily living) in the linear regression model illustrate the buffering or moderator effect of physical activity and activities of daily living (Table 7/ S1).

Physical activity is able to significantly buffer the effects of stress on all analyzed health complaints, except for gastrointestinal and heart complaints. In contrast, activities of daily living are no significant buffering variable. The relationship between perceived stress and reported health complaints is lower with rising energy expenditure due to physical activity, however, not with rising energy expenditure due to activities of daily living.

The hierarchical presentation of the results (Table 6 / S1 and Table 7 / S1) allows to comprehend the explained variance (R^2) gains due to the interaction terms (Gerber & Pühse, 2009). The presented model shows gains in the explained variance between +0.7% and +2.4%. Physical activity is a potential moderator especially for limb pains. For mental complaints concerning fatigue symptoms the effect is a bit lower (Gerber & Pühse, 2009).

In a further differentiation, age and gender are included in the linear regression model (Table 8 / S1).

Table 8 / **S1:** Results of the linear regression model: stress, physical activity (PA) / activities of daily living (ADL), and the interactions (stress*PA; stress*ADL) on various health complaints controlled for age and gender

	Activity	Constant		Main effects		Interac.	Overall Model				
		Gender	Age	Stress	Activity	Stress* Activity	R^2	F	df	n	p
overall score of health complaints[a]	PA	.08	.15**	.39**	-.15**	-.12**	.18	17.32	5	372	<.01
	ADL	.18	.01**	.39**	.07	-.02	.15	14.81	5	374	<.01
physical complaints[b]	PA	.07	.18**	.34**	-.16**	-.10*	.15	14.57	5	385	<.01
	ADL	.16	.01**	.35**	.08	.002	.13	12.44	5	387	<.01
mental complaints[b]	PA	.11*	.06	.36**	-.13**	-.10*	.17	17.28	5	397	<.01
	ADL	.20*	.004	.37**	.04	-.06	.15	14.74	5	402	<.01
fatigue symptoms[a]	PA	.11*	.06	.36**	-.13**	-.10*	.17	17.28	5	397	<.01
	ADL	.20*	.004	.37**	.04	-.06	.15	14.74	5	402	<.01
gastrointestinal complaints[a]	PA	-.04	.07	.27**	-.10*	-.02	.08	7.65	5	399	<.01
	ADL	-.07	.01	.28**	-.01	.03	.07	7.04	5	403	<.01
limb pains[a]	PA	.13**	.18*	.27**	-.18**	-.15**	.15	14.73	5	406	<.01
	ADL	.29**	.01**	.27**	.10*	-.04	.11	10.87	5	409	<.01
heart complaints[a]	PA	.06	.23**	.31**	-.08	-.04	.12	12.33	5	400	<.01
	ADL	.16	.02**	.31**	.11**	-.1	.13	12.64	5	405	<.01

Note: Results of the regression analyses: B-Coefficient and significance of main effects and interaction terms of stress, physical activity (PA), and activities of daily living (ADL), characteristics of the overall model controlled for age and gender; z-standardized variables; significance level: p ≤ .01 (**), p ≤ .5 (*)
[a] All depend variables (types of health complaints) are sum scores of different singe items representing that health complaint (Brähler et al. 2008); [b] Calculation of categories by combining the subscales: physical complaints: Gastrointestinal complaints, limb pains, and heart complaints; mental complaints = fatigue symptoms

For mental complaints / fatigue symptoms, gender has a significant relationship (Table 8 / S1). Women report higher amounts of mental complaints and limb pains than men (Table 5 / S1). The buffering effect of physical activity is significant for both genders. Even though women report higher amounts of mental complaints and limb pains, physical activity reduces the perception of both complaints.

The individual age is important for the overall score of health complaints, and physical complaints such as limb pains and heart complaints. As assumed, older participants report higher amounts of health complaints than younger participants (Table 5 / S1). Even for older participants when health complaints are manifested, the buffering effects of physical activity remain significant.

For activities of daily living, age and gender have no effects – activities of daily living remain non-significant for the buffering effect (Table 8 / S1).

Interesting results arise for the analysis of heart complaints: neither physical activity nor activities of daily living are in a positive (meaning reducing) relationship. Activities of daily living are significantly negatively related with heart complaints. This means, participants spending high amounts of energy with activities of daily living, report more heart complaints than inactive participants (inactive / very low energy expenditure (0-39.41kcal): M = 2.36; SD = 2.72; low levels of energy expenditure (40-258.16kcal): M = 3.24; SD = 2.89; average levels of energy expenditure (259-76.,04 kcal): M = 2.14; SD = 2.27; high amount of energy expenditure (>765 kcal): M = 3.54; SD = 3.16 – $r = 0.150$, $p < .01$). These results are independent of the perceived stress level.

Discussion

The purpose of this study was to research buffering effects of physical activity and activities of daily living according to negative stress-induced effects on individual health.

According to the presented literature results, this study shows the assumed relationships between individual perceived stress, physical activity, activities of daily living, and individual reported health complaints: Higher amounts of stress are related with higher amounts of physical and mental health complaints (Cohen et al., 2007; Gerber & Pühse, 2009; Morrison & Bennett, 2009). In contrast, physical activity seems to reduce the perception of health complaints, i.e. higher energy expenditure due to physical activity is related to less physical and mental health complaints. This result corresponds as close as possible with other study results (Ensel & Lin, 2004; Nguyen-Michel et al., 2006; Taylor, 2000). In contrast to physical activity, activities of daily living are not associated with the perception of health complaints in this study. This result is unexpected when compared to other study results (Blair, Kohl & Gordon, 1992; Carmack, Boudreaux, Amaral-Melendez, Brantley & De Moor, 1999). Carmarck et al. (1999) support the hypothesis, that only the amount of energy expenditure is responsible for beneficial health outcomes, however, not the way how this energy expenditure is achieved. With the available data, this assumption, however, cannot be accepted. For heart complaints, it is obvious that with increasing activities of daily living reports of heart complaints increase as well. The effect of age can be an explanation. As described within the study description, older participants expended more energy through activities of daily living, and at the same time, older participants reported more heart complaints than compared to younger participants. Although when controlled for age in the regression models, the relationship between activities of daily living and heart complains persist. A higher energy expenditure due to activities of daily living is significantly related with more reported heart complaints ($r = 0{,}15$, $p < 0{,}01$). Further variables seem to be important. It is conceivable that individuals with diagnosed heart complaints are told to be more physically active, however, the individual strength and endurance is not sufficient for physical exercises. Thus with rising age, more individuals with diagnosed heart complaints may resort to a more active lifestyle.

The significant interaction terms in the regression analyses show that physical activity acts as a moderating / buffering variable in the relationship between individual perceived stress and reported health complaints. However, this buffering effect is not consistent for all researched health complaints; gastrointestinal and heart complaints could not reach a significant interaction term. Thus, physical activity could not buffer the negative effects of stress for all health complaints. For this reason, in the context of stress and physical activity, health complaints should be analyzed more differentiated and in more detail.

According to activities of daily living, no buffering effect could be demonstrated. This means, in this context the amount of activity a person realizes during his daily life seems to be irrelevant for individual health. Physical activity alone has a buffering effect.

For the found buffering effects, literature provides different explanations. On the one hand, physical activity and related physical fitness enhances individual physical resources, which may have positive effects on stress-induced back or neck pain. On the other hand, physical activity seems to provide a mental detachment from daily life and demands, which protects and / or enhances mental and emotional personal resources (Sonnentag, 2012). With this assumption, the found positive effects of physical activity on mental complaints can be explained. In this study these effects are obvious for fatigue symptoms representing mental complaints. Here physical activity may act as a buffering variable. However, this buffering effect on mental complaints is lower than for physical complaints (e.g. neck, back, or shoulder pain). Compared to physical complaints such as back pain, for which physical activity may have a direct effect, for mental complaints it seems to be reasonable, that physical activity goes in line with a mental detachment (Sonnentag, 2012). However, it may not be possible for each person and with each physical exercise to reach a mental detachment. This may explain the lower buffering effect of physical activity for mental complaints.

The presented study limits mental complaints to fatigue symptoms. However, it is thinkable, that physical activity acts as a buffering variable also for other stress-induced mental complaints, such as a depressive mood. In further studies, this differentiation should be considered.

According to the perception of stress and health complaints, results indicate differences between both sexes and age groups, which may affect the buffering effect of physical activity. Women report more mental complaints and limb pains compared to men. A possible reason for this may be the gender differences in reporting health complaints. It seems that overall men report less health complaints than women (Mehrbach & Brähler, 2004). These differences become especially obvious for mental complaints (Lademann & Kolip, 2005). It remains to be determined whether this difference is due to the fact that women actually have more complaints or whether men only reported less discomfort.

Relevant is also the individual age of the participants. The results indicate that with rising age, higher amounts of health complaints are reported (Lademann & Kolip, 2005). It is assumed, that with rising age, manifest health complaints cannot be improved, or only to a less positive effect, with physical activities or activities of daily living. To improve chronicle health complaints in higher age such as osteoporosis in women, higher amounts of physical activities or activities of daily living are necessary (Dishman et al., 2004). This fact should also affect the buffering effect of physical activity and activities of daily living on stress-induced health complaints in higher ages. The results indicate that the relationship between stress, physical activity, activities of daily living and physical and mental health complaints is more complex than assumed.

The decision to be physically active or not, depends on various individual factors, such as individual attitudes, motives, and affective ratings. These factors are not only important for beginning and maintaining physical activity, but also for the subjective appraisal of these activities (Niermann, 2011). This appraisal of physical activity seems to be important for the protective effect on various health complaints. It is likely that physical activity does not equally strengthen or protect personal resources for all people. Moreover, it is assumed, that the positive effect of physical activity differs according to personal factors such as individual motives, affective appraisals, and attitudes, and according to external factors such as living and working conditions. Further studies should include individual personal and external factors to research which activities may be beneficial for stress-induced health complaints.

Limitations

Data basis of this study is a voluntary communal health study. Within voluntary health studies, a certain study bias exists – most participants are very interested in health topics, resulting in that those participants are also healthier, more active and have a healthier lifestyle than other people who are not interested in health topics (Jungbauer-Gans & Gross, 2006).

The energy expenditure of physical activity has been calculated with the subjective report of physical activities, the duration of each exercise sessions, and the amount of active weeks during the year according to the model of Ainsworth et al. (1983). Equivalent to this, the energy expenditure of activities of daily living has been calculated using the daily amount of cycling and walking. Both calculations may include that participants have over- or under-estimated their daily activities (Haugland et al., 2003) or classified their activities into the wrong category, e.g. cycling for grocery shopping as physical activity and not as activities of daily living. Furthermore, no information about the intensity, which is important for the actual energy expenditure of the physical exercise, was included. The presented energy expenditures of physical activity and activities of daily living have high standard deviations, which may be the result of this inaccurate assessment. To overcome this problem, the usage of objective measurements such as accelerometers or fitness tests could be a beneficial alternative.

The usage of objective measurements may enhance the assessment of health complaints as well. Objective diagnoses of a physician or results of blood tests would give more information about true health complaints.

Further perspectives

The analysis was able to differentiate the view of the potential buffering effect of physical active and activities of daily living in the relationship between perceived stress and individual health complaints. However, in further studies some further points should be integrated.

In further studies, the relationship and interaction between physical activity and stress should be researched in detail. The different directions of this relationship should be highlighted. Special need to clarify exists, especially which effect individual perceived stress (e.g. through a lack of time) has on the individual physical activity level, and for which persons this potential effect has the most consequences (e.g. Single-parent families or full time employed persons). It also needs to be clarified if different sources of stress have different effects. Therefore, it is unclear, if the relationship between physical activity and stress varies according to the reason of stress (e.g. family or work) and if physical activity in turn affects the different reasons of stress. Thus, it is necessary to include theoretical models to demonstrate and explain the relationship between individual perceived stress, different reasons for stress, and physical activity. Furthermore, personal characteristics such as motives or affects, and elements of the social environment, should be integrated.

A further point, which should be included in further research projects is the time instability or time fluctuation of both stress and physical activity (Klaperski et al., 2012b). This fact requires an assessment over time such as a diary study approach.

As mentioned above further research, assessment and interpretation of results should be grounded on a theoretical basis.

Summary and Conclusion

The study was able to demonstrate that physical activity, however, not activities of daily living, act as a buffering variable in the relationship between perceived stress and health complaints. The effect seems to be stronger for physical than for mental health complaints. Further research should highlight the relationship between perceived stress and physical activity, and the effect of additional variables to verify the question as to which variables and individual characteristics are important in this relationship.

To sum it up, the results of the presented study as well as the results of the literature about the buffering effect of physical activity in the stress-health relationship underline the following overall conditions for a buffering effect (Fuchs & Klaperski, 2012; Gerber & Pühse, 2009):

- *Physical activity or physical fitness:*

  The buffering effect could be found in studies using self-reported and objectively assessed physical activity as well as physical fitness. However, study 1 indicates, that activities of daily living are not able to buffer negative effects of stress on individual health.
- *Physical or mental health*:

  Additionally to different physical activity variables, the buffering effect could be found for different health variables – physical activity may moderate the effects of perceived stress on physical as well as on mental health. The results indicate that physical activity is a slightly stronger buffer for physical than for mental health complaints (Gerber & Pühse, 2009; Latimer, Martin Ginis & Hicks, 2005).
- *Study design:*

  Both cross-sectional, as well as experimental studies, found buffering effects of physical activity.

  Results of experimental studies indicate that higher intensity physical activity is needed to reach a significant buffering effect (Norris et al., 1992). These results underline the results of study 1, in that activities of daily living do not act as buffering variables. A minimum of intensity seems to be needed to reach a significant moderator effect of physical activity on the effect of perceived stress on health.
- *Dose-response relationship:*

  Results of different study designs lead to the question about the dose-response relationship - How do I have to train to reach a significant stress buffering effect? Literature results indicate, that a minimum of intensity, duration, and frequency during the week is necessary to achieve a significant buffering effect (Fuchs & Klaperski, 2012; Gerber et al., 2014; Gerber et al., 2010; Kaluza et al., 2001; Norris et al., 1992). It has been shown that 2-4 times per week, sessions with 45-60 min each, and an intensity of 70-75% of the maximum heart rate (Fuchs & Klaperski, 2012) is beneficial.

- *Endurance vs. resistance training*:
  The buffering effect of physical activity could be demonstrated for aerobic exercises (Brown, 1991; Norris et al., 1992; Roth & Holmes, 1985), in contrast, anaerobic exercises have not yet been researched separately. Only one study differentiated between aerobic and anaerobic exercises and found a slightly stronger effect for aerobic exercises (β_{aerob} = -.32 vs. $\beta_{anaerob}$ = -.23) (Brown, 1991).

The presented results show that physical activity seems to be an important factor in the stress-resources-health context.

However, despite the presented findings of positive effects of physical activity on the perception and effects of stress, different facts remain unclear (Fuchs & Klaperski, 2012).
Firstly, the physiological mechanisms of physical activity in regulating stress remain unknown. Research demonstrates that physically active people have less physiological reactions to stressful situations (Gerber, 2008, 2012; Klaperski et al., 2013); however, the biochemical mechanisms require more research.
Secondly, besides the unknown physiological mechanisms, the conceptional factors of physical activity are mostly unknown as well. Which duration, frequency, and fashion of physical activity (endurance or strength training) are most beneficial? (Fuchs & Klaperski, 2012) Literature results suggest different key elements and conditions; however, a guideline or exact recommendations are not possible. More research with different physical activities (endurance vs. resistance training), different settings and participants, different age groups, and different study designs are necessary. Additionally it remains unclear, how beneficial physical activity may be in comparison to other stress regulatory techniques such as relaxation techniques, psychotropic medicine or sleep.
Although, the presented results show this relationship in various angels, more research is necessary to find the underlying mechanisms and to explain found effects.

Stress and physical activity

The presented literature and study results focus on the effects of physical activity on the perception of stress and on the effects of stress on individual health. However, as described above, the other direction of the relationship between physical activity and stress (Figure 6), that means the effect of individually perceived stress on individual physical activity, is also plausible and part of the model of Fuchs, Hahn, and Schwarzer (1994).

This direction, the effect of perceived stress on physical activity, represents one major research direction in this dissertation. It is researched in two further studies (Study 2 and 3)

In a first step, a theoretical framework, the Social Cognitive Theory, explaining individual behavior in the person-environment context is promoted. Within this Social Cognitive Theory framework, the development and effects of individually perceived stress are grounded and presented. Using this basic theoretical model Study 2 focuses on the effect of stress on individual, as well as inter-individual health behavior. Study 3 focuses on the effects of daily perceived stress on daily physical activity in a day-to-day approach.

Chapter 3: Social Cognitive Theory and individual stress

Nobody lives alone in a separated and unique bubble of the universe – human beings are social individuals, living individual lives in permanent reciprocal interaction with the social and material environment around them. This interaction, between the person themselves, their personal characteristics such as perceptions, feelings, emotions, and personality, and the environment the person lives in, constitutes the meaning and course of an individual life and the development of social groups and social systems (Neyer & Asendorpf, 2012; Shiner, 2011).

This person-environment interaction builds the basic element of human development and social life. However, Albert Bandura (1986, 1989b) expanded this bipolar interaction in his Social Cognitive Theory to a triadic reciprocal interaction between the elements – the *person*, with their personal characteristics such as cognition, feelings, perceptions, emotions, knowledge, and skills etc.; the *behavior*, through which the person behaves, represents, and expresses themselves in the interactions; and the *environment* as the social and material surrounding of the person in which they react. These three components – the person, the behavior, and the environment – operate as interacting determinants that influence each other (Bandura, 1986, 1989b). Figure 8 demonstrates this reciprocal interaction between the person, his behavior, and the environment.

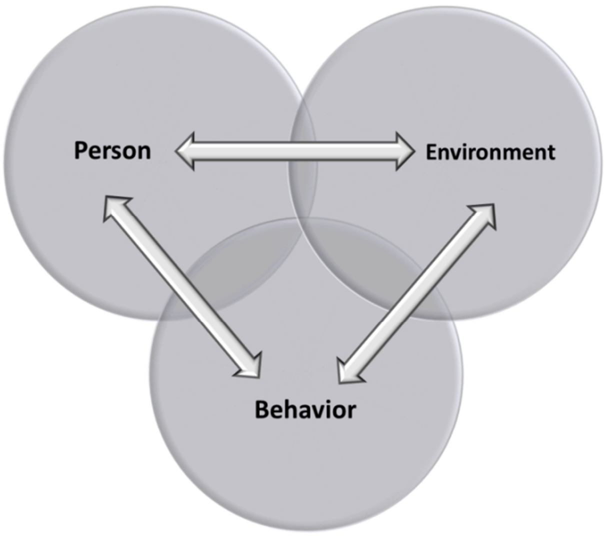

Figure 8: Reciprocal interaction between person, behavior, and environment - Social Cognitive Theory (modified Bandura, 1989)

Social Cognitive Theory

As a first step and for a clearer understanding of the triadic reciprocal interaction within the Social Cognitive Theory and the development of individual stress within this model, a detailed review of the constituents and relationships is necessary. In a second step, the development of stress within the Social Cognitive Theory is discussed.

Person – Behavior:

The person-behavior interaction reflects the individual relationship between the constituents of personality, such as thoughts, moods, expectations, goals, intentions, emotions, affects, self-efficacy, or self-confidence, and the resulting behavior. Expectations, goals, perceptions, and intentions are necessary for the shape and direction of intentional and goal-directed behavior – "what people think, and feel, affects how they behave" (Bandura, 1989, 3). Individual behavior, e.g. being physically active, is affected by the person and their actual thoughts, goals and self-efficacy, e.g. not going jogging due to being tired from a long working day. In turn, extrinsic effects of the behavior, e.g. the results of a physical activity lesson, may determine the person's thoughts and feelings such as feeling satisfied and happy after a physical activity lesson. On the other hand, individual emotions, such as self-efficacy, knowledge, and experience give an individual manner to the behavior (Bandura, 1989b).

Person – Environment:

The second relationship within the Social Cognitive Theory model is the interaction between the person and the individual environment the person lives in. In detail, it is the interaction between the person's characteristics and the social and material environmental influences. People's expectations, beliefs, goals, and cognitive skills are developed and modified by social influences through the social environment. Social interactions within the environment convey information and activate emotional reactions through modeling, instructions, and social norms (Bandura, 1986, 2004; Repetti, Wang & Saxbe, 2009). For example, in the field of health and health perceptions, the health climate of the social environment, e.g. the family, may affect the individual perception of what is healthy and what is not – the perceived family health climate in which a child is raised, seems to affect the individual perception and in turn the actual health behavior (Niermann, Krapf, Renner, Reiner & Woll, 2014).

People also produce behavioral and non-behavioral reactions which differ from their social environment by their appearance, physical characteristics, such as age, race, size, and physical attractiveness, and socially awarded roles and status, independent of what they say or how they behave (Bandura, 1989a, 1989b). Thus, with their social status or observable characteristics and appearance, people can affect their social environment prior to saying or doing anything (Bandura, 1989b) by affecting the other's assumptions, pertaining to previous experiences and personal characteristics of the social other.

Environment – Behavior

The third relationship in the Social Cognitive Theory framework is the relationship between the environment the person lives in and the person's behavior. Bandura wrote: "in the transactions of everyday life, behavior alters environmental conditions and is, in turn, altered by the very conditions it creates" (Bandura, 1989b, 4). This means, if a person interacts with a certain situation specific environment, such as certain other persons or certain physical environmental aspects, the behavior of the person interacts with these elements. It may affect them and in turn may be affected by them; however, only if a direct interaction occurs and the potential environment becomes an actual environment (Bandura, 1989b). A lecturer may influence the student but only when the student attends his or her class, and very importantly, only when the student pays attention to the lecturer. In turn, the lecturer may change his or her class, if the students pay more attention to their individual conversations and not to the lecturer. Another example can be found for health behavior; if a person, for example the mother, has no time for grocery shopping, the child, as a part of the social (family) environment, is not able to eat fresh food for lunch (LaGuardia & Patrick, 2014).

These reciprocal influences show that people are both producers and products of their environment. They live in a certain environment with their personal characteristics such as emotions, thoughts, or goals. They influence the environment, in turn are influenced as a person themselves, and behave accordingly in this environment (LaGuardia & Patrick, 2014). The three components reciprocally affect each other through their permanent interaction. However, within this reciprocal interaction the elements do not influence each other in equal strength and not always simultaneously. The strength and time of reciprocal influences depend on the situation, the individual situation specific personal elements, the individual situation specific behavior, and the situation specific environment (Bandura, 1989b).

Development of stress in the Social Cognitive Theory framework

The reciprocal interaction between the person, their behavior, and the social and physical environment constitutes individual daily life. However, within this interactional framework, the elements are not balanced at every moment in time – thus individual stress may occur.

Gerrig and Zimbardo (2008) define stress as the physiological, behavioral, emotional, and cognitive response of an organism to internal or external stimulus events that disturb the individual equilibrium and tax or exceed its ability to cope with this disturbance.

This extensive definition of stress and its results includes a variety of elements and effects of the development and perception of stress.

First of all, stress occurs in situations, in which demands exceed the person's resources to handle the situation. Therefore, in a first step, the individual compares, according to the transactional model of stress, the given demands with their available resources (Lazarus & Folkman, 1986). Both, demands and resources, could be internal as well as external (Table 9) (Gerrig & Zimbardo, 2008b; Hobfoll & Ford, 2007; Lazarus, 2012).

Table 9: Examples for internal and external resources and demands

Personal Resources		Individual Demands	
internal	external	internal	external
Self-efficacy	Social support	Persons goals, norms, and values	Time pressure in the job
Self-concept	Access to help or knowledge	Worries about the future	Overload of tasks
Self-esteem		Dissatisfaction with a certain behavior and/or the results	Conflicts and discussions
Knowledge or cognitive skills			

The combination of external and internal demands and external and internal resources provides the basis for the individual situation specific appraisal of a situation. If the demands, independent of being internal or external, exceed the given resources, the person appraises the situation as threatening. As a results, stress accrues as a product of the interaction between the person themselves and their environment – Figure 9 (Lazarus, 2012; Lazarus & Folkman, 1986).

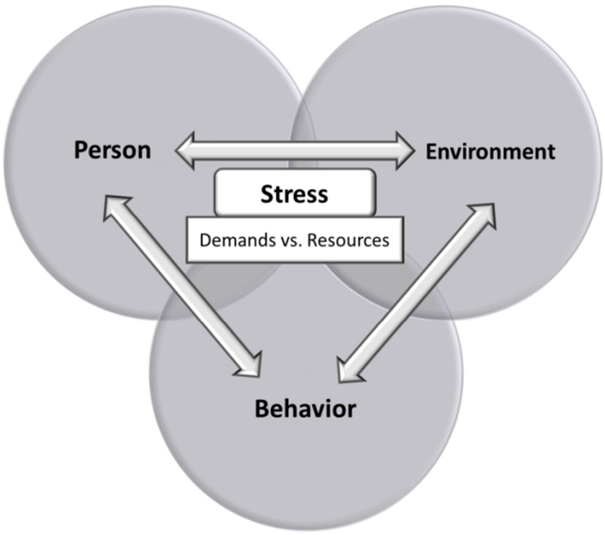

Figure 9: Development of stress in the Social Cognitive Theory (modified Bandura, 1989)

After the appraisal of a situation as threatening or stressful, physical, mental and emotional reactions within the person begin (Lazarus, 2012; Lazarus & Folkman, 1986). On the on hand, physiological reactions start independently after the perception of stress. Physiological reactions to stress are, for example, the inflammation of the human organism caused by the release of cortisol, cortisone, epinephrine, and norepinephrine, the most important stress hormones, which lead to an increase of blood pressure, heart rate, blood vessel dilatation, and glycogen level in the blood (Everly Jr. & Lating, 2013b; Rice, 2012; Seaward, 2011). These are all physiological reactions which are necessary to prepare the human organism for fight or flight and have helped humans to survive threatening situations during the development of mankind (Gerrig & Zimbardo, 2008a).

On the other hand, the person starts to cope with the situation in a more conscious way. Coping behavior summarizes all individual behavioral reactions to a stressful situation, how to handle the situation itself, and the results of the situation. Lazarus (1966) and Lazarus and Folkman (1986), the authors of the transactional model of stress, distinguish two basic forms of coping: *problem focused coping* and *emotion focused coping*. Problem focused coping represents all efforts made by a person to handle the stressor itself such as the problem, the demand, or the conflict. For example, in the case of time pressure, problem focused coping means to make a systematic To-Do-list in order to get an overview of necessary tasks. In contrast, emotion focused coping represents all efforts made to handle the emotions, such as anger, ego-depletion or sadness, accompanying a stressful situation. Positive thinking or a change in behavior, such as eating chocolate or being physically active, can be emotion focused coping strategies.

To sum it up, a stressor, be it internal or external, leads to physical, mental, behavioral, and cognitive reactions of a person in order to handle the situation and to return to a state of equilibrium (Gerrig & Zimbardo, 2008b). These individual physical, mental, behavioral, and cognitive reactions are linked to personal health. Therefore stress may have positive effects, e.g. through stimulation of the organism and a more focused view of a problem (Gerrig & Zimbardo, 2008b). However, intensive and prolonged stress has mostly negative effects on the individual health and is linked to the development of health complaints. Lighter illnesses arise if the stress is intensive and / or occurs often and may lead to diseases, if the stress is prolonged or chronic. Stress may have diverse effects on a person; stress may have direct effects, through physiological reactions, which may lead to health complaints and diseases; and indirect effects by changing the individual health behavior of a person, which in result leads to an unhealthy behavior and as a consequence, the development of noncommunicable diseases (Cohen et al., 2007; Steptoe, 1991).

Effects of stress…

According to the Social Cognitive Theory, stress may occur in every interaction between the three elements of the model – person ↔ environment; person ↔ behavior; and behavior ↔ environment – and in turn affect each element and interaction itself.

The following paragraphs very briefly summarize the research results of direct effects of stress[8] on the person, the behavior, and the environment, as well as the effects on the interactions between the three elements (Figure 10).

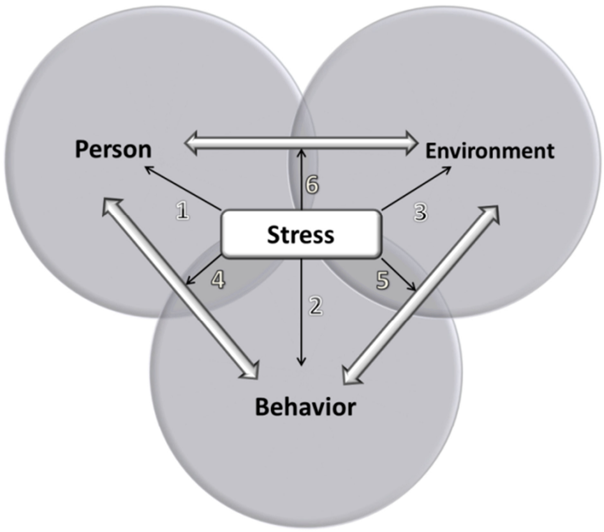

Figure 10: Effects of stress on the elements and interactions according to SCT

8 This section summarizes the effects of individual perceived stress on the person himself, his or her behavior and his or her environment according to the Social Cognitive Theory, not to mistake with the presented effects in Chapter 2. Chapter 2 focuses on the effects of physical activity on the person himself and individual health.

… on the person

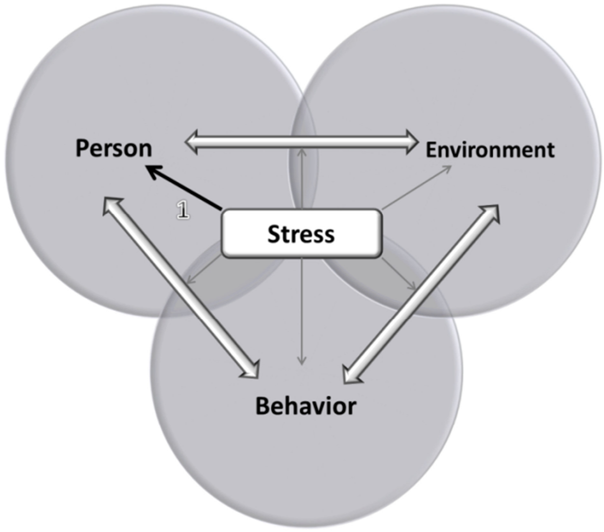

Figure 11: Effects of stress on the person according to SCT

The direct effect of individually perceived stress on the person (Figure 11) themselves is well researched throughout different research disciplines (medicine, psychoneuroimmunology, and health psychology). Different research disciplines, perspectives and analyzing methods (questionnaires vs. biomarkers (Everly Jr. & Lating, 2013a; Videan et al., 2009)), show that direct effects of stress on the person and their health are mostly caused by physiological reactions to stress, that is, biochemical reactions to a stressful situation and their mostly negative and prolonged effects on the human organism. The appraisal of stress automatically triggers a cascade of various physiological stress responses (activation of the sympathetic nervous system, activation of the neural axis, activation of the neuro-endocrine axis, and, if the stressor lasts longer than approximately 20-30 minutes, activation of the three endocrine axes, the ACTH / HPA axis, the ADH axis, and the thyroxin axis (Everly Jr. & Lating, 2013b; Seaward, 2011)) and the release of different hormones (cortisol, cortisone, epinephrine, and norepinephrine (Everly Jr. & Lating, 2013b)) which cause a general inflammation of the organism. These acute reactions enable the organisms to react to the external stressor. Table 10 provides a brief overview of acute physiological stress effects of the body.

Table 10: Physical reactions to orgasm inflammation (Everly Jr. & Lating, 2013b)

Target system	Physiological reaction
Cardiovascular system	Increased arterial blood pressure Increased heart rate and cardiac output Increased blood supply to brain Decreased blood flow to the kidney Decreased blood flow to gastrointestinal system Decreased blood flow to skin
Organ and musco-sceletal system	Increased stimulation of skeletal muscles Exacerbation of gastric irritation Decreased kidney function
Immune system	Decreased immune mechanisms
Metabolic System	Increased plasma free fatty acids, triglycerides, cholesterol Increased glucose production (gluconeogenesis) Increased urea production Increased ketone body production

When the stressor disappears and the reactions are not needed anymore, the organism activates the parasympathetic nervous system and reverts to the equilibrium (Everly Jr. & Lating, 2013b). In this case, no or only few effects remain on the organism. In contrast, if the organism is prolongedly or chronically inflamed, the change in the hormone balance caused by the excessive release of stress hormones and its effects on the organism, has various negative effects on the individual health (Everly Jr. & Lating, 2013b; Kaluza, 2012; Seaward, 2011).

The effects of physiological stress responses and the development of diseases, as mentioned above, is well researched. To sum it up, important health complaints and symptoms, resulting from perceived acute and prolonged stress, can be categorized as follows: (1) cardiovascular diseases (CVD) (2) various pains and aches, (3) gastrointestinal complaints, and (4) emotional and mental health issues (El Ansari et al., 2013; Stock et al., 2003).

(1) Cardiovascular diseases

An enormous amount of literature provides evidence for a link between individually perceived stress and CVD morbidity and mortality (Backe, Seidler, Latza, Rossnagel & Schumann, 2012; Steptoe & Kivimäki, 2012). In detail, the development of high blood pressure (hypertension), coronary heart diseases

(CHD), arteriosclerosis, and strokes are related to the perception of major life events, daily hassles, work related stress, and stress due to social isolation or conflicts (Aboa-Eboule et al., 2007; Arnold, Smolderen, Buchanan, Li & Spertus, 2012; Bonde et al., 2009; Chandola et al., 2007; Eaker, Sullivan, Kelly-Hayes, D'Agostino & Benjamin, 2004; Greenwood, Muir, Packham & Madeley, 1996; Gullette et al., 1997; Heslop et al., 2001; Kivimäki et al., 2012; Moller, Theorell, de Faire, Ahlbom & Hallqvist, 2005; Rukavina, Broborovic, Fazlie, Sovic & Civljak, 2012; Steptoe, 2007a; Steptoe & Kivimäki, 2012; Strobel, Kennardy & Aroney, 2003; Toivanen, 2011; Werner et al., 2012).

However, the mechanisms for the development of CVD caused in relation to perceived stress have not yet been clarified in detail. A plausible explanation for this increased risk of coronary heart disease may be metabolic changes and the development of intra-arterial plaques caused by the residue of free fatty acids and cholesterol which are released for the energy metabolism as a direct stress response (Seaward, 2011). Another plausible mechanism may be that increased blood pressure in reaction to stress, a dysfunction in the down-regulation of the cardiovascular system after the stressful situation, and a lower heart rate variability, will lead to the development of hypertension and an increased risk of CVD (Caspi, Harrington, Moffitt, Milne & Poulton, 2006; Chandola et al., 2007; Everly Jr. & Lating, 2013b; Fauvel & Ducher, 2007; Hawkley, Masi, Berry & Cacioppo, 2006; Hawkley, Thisted, Masi & Cacioppo, 2010; Shankar, McMunn, Banks & Steptoe, 2011). Despite these supporting results for hypertension and heart rate variability as mediators between perceived stress and the development of CVD, other studies could not support a conversion of temporary blood pressure elevation to chronic high blood pressure and the development of hypertension in relation to long-term stress (Cozier et al., 2006; Kahn, Medalie, Riss, Neufeld & Goldbour, 1972; Kivimaki et al., 2007).

A further reason being discussed is a dysregulation of the HPA axis, which may result in a disturbance of the circadian rhythm of cortisol and the development of the metabolic syndrome (Bjorntorp & Rosmond, 2000; Chandola et al., 2007).

This brief overview of literature demonstrates that perceived stress is directly linked to the development of CVD and CVD events. However, the physiological mechanisms are not clarified in detail.

(2) Various pains and headache

Various studies demonstrate, that stressed people report higher amounts of pain, e.g. muscle, back or shoulder pain, and headache than unstressed people (Britton, 2013; Hartfiel et al., 2012; Lochbaum, 2004; Lovgren, Gustavsson, Melin & Rudman, 2014; Nash & Thebarge, 2006; Stock et al., 2003; Sundblad, Jansson, Saartok, Renström & Engström, 2008; Wiklund, Malmgren-Olsson, Ohman, Bergstrom & Fjellman-Wiklund, 2012). Studies conducted with students found that the perception of various pains, such as back and shoulder pains, headaches, and migraines, increases with the increase of perceived stress before and during exams (AlGhamdi & Al-Sheikh, 2009; Menon & Kinnera, 2013; Stock et al., 2003)

Similar to the development of CVD caused by perceived stress, the mechanisms responsible for physiological stress responses causing different pains, are not yet clear. It is possible, that the release of epinephrine causes an hyperstimulation of the muscles. A prolonged stimulation of the muscles may lead to a higher muscle tonus, which may then constrain nerves and lead to muscle and joint pains (Strobel, Hunt, Sullivan, Sun & Sah, 2014).

(3) Gastrointestinal complaints

Gastrointestinal symptoms are characteristics for another group of stress related diseases. In various studies, 50 to 65% of all stressed participants report at least one gastrointestinal symptom such as esophageal symptoms, upper dysmotility symptoms, bowel symptoms, diarrhea, and constipation (Lee, Mun, Lee & Cho, 2011; Norton, Norton, Asmundson, Thompson & Larsen, 1999; Suarez, Mayer, Ehlert & Nater, 2010). It seems that gastrointestinal complaints are the result of a decreased blood and liquid flow to the organs, resulting in a reduction of gastrointestinal activity (Everly Jr. & Lating, 2013b). Additionally, a changed nutrition during stressful periods, such as the consumption of a higher amount of snacks and coffee, may lead to digestion problems and gastrointestinal symptoms (Boekema, Samsom, an Berge Henegouwen & Smout, 1999).

(4) Emotional and mental health issues

The link between perceived stress and emotional and mental health complaints is not a novelty. An enormous amount of studies have researched and detected, that stress is linked to mental diseases such as depression (Coon, 2004; Gerrig & Zimbardo, 2008b; Hammen, 2005; Polter & Kauer, 2014; Rathus, 2004; Sawatzky et al., 2012; Weiten, 2004), burnout (Balch & Shanafelt, 2010; Finney, Stergiopoulos, Hensel, Bonato & Dewa, 2013; Hämmig, Brauchli & Bauer, 2012; McCormick & Barnett, 2011; Rossler, 2012; Santen, Holt, Kemp & Hemphill, 2010), and fatigue (Wood, Bentall, Gopfert, Dewey & Edwards, 1994).

The responsible physiological mechanism for mental effects of stress responses seems to be an over activity of the hypothalamic-pituitary-adrenal (HPA) axis as a direct response to stress. This leads to the release of a high amount of corticotrophin releasing hormone (CRH) in combination with the release of high amounts of epinephrine, which is followed by depressive symptoms (Everly Jr. & Lating, 2013b; Hammen, 2005; Pariante, 2003). In addition to these physiological responses, missing personal resources such as social support, insufficient coping strategies, and low self-oriented competences, e.g. self-confidence or self-esteem, are important factors in the development of mental health conditions caused by perceived stress (Hammen, 2005).

This brief overview of the enormous study results on the effect of stress on the person demonstrates that perceived stress is directly linked to health and the development and progress of diseases. Besides the direct effects of perceived stress on the person, stress has effects on the individual behavior, which in turn affects the personal health.

… on (health) behavior

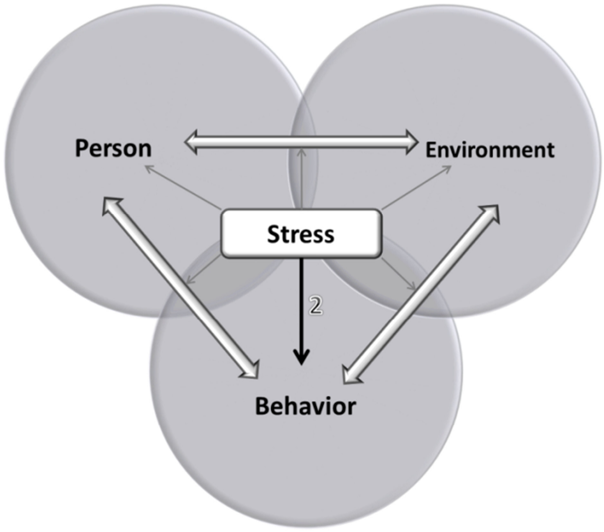

Figure 12: Effects of stress on individual (health) behavior according to SCT

Individual behavior is affected by individual perceptions, feelings, and emotions (Coon, 2004); and thereby by perceived stress as well (Figure 12). Concerning individual health, the effect of perceived stress on individual health behavior is, as mentioned above, discussed as an important effect in the stress-health relationship (Steptoe, 1991), and could be, beyond direct physiological stress responses, responsible for negative health outcomes related to stress.

The effects of stress on individual health behavior, such as physical activity, sedentary behavior, nutrition, alcohol and drug consumption, smoking, and risky sexual and overall behavior are discussed in this paragraph. Each type of health behavior is affected by perceived stress individually, as well as the combination of different health behavior profiles. Therefore, the perception of stress may lead to a reduction in physical activity, an increase in time spent with sedentary behavior, the more frequent consumption of higher amounts of snacks, the consumption of more alcohol and cigarettes (Landsbergis et al., 1998; Mouchacca, Abbott & Ball, 2013; Ng & Jeffrey, 2003; Roohafza et al., 2007).

Overall, individually perceived stress leads to a mostly negative change in individual health behavior, resulting in the development of illnesses and diseases (Heikkilä et al., 2013; Mouchacca et al., 2013).

(1) Physical activity

With regard to the effect of perceived stress on physical activity, literature provides inconsistent findings. A recently published review analyzed 168 studies on the effects of perceived stress on physical activity and exercise. 79.8% (n=152) of the analyzed studies support the hypothesis that stress has effects on physical activity and exercise, independent of the direction this influence has (Stults-Kolehmainen & Sinha, 2014). Of these 152 studies, most (n=123) report a negative effect, i.e. a reduction of physical activity and exercise during and after stressful situations. In contrast, 29 studies found an opposite trend. The remaining 34 studies found no relationship or conflicting results.

The authors discussed different reasons for these inconsistent results. First of all, most studies have a cross-sectional study design. Individual differences and indications of the direction of influence cannot be given. Especially individual differences are important factors concerning the appraisal and effects of perceived stress. Since individuals behave individually, i.e. some increase their activity level, using physical activity as an emotion focused coping strategy to detach from a stressful situation (Feuerhahn, Sonnentag & Woll, 2012; Sonnentag et al., 2010; Sonnentag & Jelden, 2009), while others reduce their activity level due to depleted personal resources (Lutz, Stults-Kolehmainen & Bartholomew, 2010; Muraven & Baumeister, 2000). A more detailed view on individual behavior on a daily level is necessary. A second very important limitation of most studies about stress and physical activity is the measurement of both variables. Stress is very time-specific and not stable over time. Recall questionnaires with short recall times (today, last week) provide benefits to reduce recall bias (Newcomer et al., 1999) and to capture direct effects of stress. Additionally, the extent of stress varies greatly in the researched studies, which diminishes the comparability of the effects. Similarly, acute physical activity is not stable over time and depends on various variables, as well of the perception of stress. Accordingly, stress may have an impact on the exercise behavior itself and how people remember it (Stults-Kolehmainen & Sinha, 2014). Objective methods of measurement of physical activity, e.g. using an accelerometer, may be a solution to capture the physical activity level in detail. A further benefit of using accelerometers is the ability to capture the full complexity of the daily physical activity beyond exercise lessons, e.g. occupational and community activity. The use of diary methods with an objective measurement of actual physical activity and detailed questions about the perceived stress, e.g. reason, intensity, or duration, provides considerable improvements for the measurement of perceived stress and its effects on physical activity.

(2) Sedentary behavior

Concerning sedentary behavior, results seem to be more consistent – higher perceived stress is linked to more sedentary time, especially watching TV (Johansson, Johnson & Hall, 1991; Laugero, Falcon & Tucker, 2011; Lundahl, Nelson, Van Dyk & West, 2013; Mouchacca et al., 2013; Rhodes, Mark & Temmel, 2012; Steptoe, Lipsey & Wardle, 1998; Steptoe, Wardle, Pollard, Canaan & Davies, 1996; Wijndaele et al., 2007). During the discussion about health and health behavior, sedentary behavior arose as an independent health risk behavior (Hamilton & Owen, 2012; Owen, Healy, Matthews & Dunstan, 2010; Owen, Sparling, Healy, Dunstan & Matthews, 2010). Not only the absence of physical activity, but also other behaviors accompanying sedentary behavior, such as an increase in snacking during sedentary behaviors like watching TV, are unhealthy (Rey-López et al., 2011; Rhodes et al., 2012)

(3) Nutrition

Research on the effects of perceived stress on individual nutrition provides more consistent results than on individual physical activity. Healthy nutrition in relation to perceived stress correlates with the choice of core foods (essential foods) and non-core foods (superfluous foods) (Johnson, van Jaarsveld & Wardle, 2011). Higher perceived stress is associated with less frequent consumption of core foods, i.e. less salad, fruit, and vegetables, and more frequent consumption of non-core foods, i.e. sweets, fatty snacks, and fast food meals (Bauer, Neumark-Sztainer, Fulkerson, Hannan & Story, 2011; Kandiah, Yake, Jones & Meyer, 2006; Oliver & Wardle, 1999; Tryon, DeCant & Laugero, 2013; Wardle, Steptoe, Oliver & Lipsey, 2000). During stressful periods, people seem to eat sweet and fatty snacks and fast food more frequently than proper meals (Boutelle, Fulkerson, Neumark-Sztainer, Story & French, 2007; Devine, Connors, Sobal & Bisogni, 2003; Jabs et al., 2007; Wallis & Hetherington, 2009). Possible explanations for these findings include the fact that time-pressure may lead to changes in the time spent on the preparation of meals and that consuming a take-out meal just saves time (Beshara, Hutchinson & Wilson, 2010; Bevan & Reilly, 2011). Moreover, perceived stress may lead to reduced self-control over food choices and food quantities (Groesz et al., 2011; Torres & Nowson, 2007).

(4) Smoking, alcohol consumption, and drug abuse

Smoking: Smoking is one of the most dangerous individual health risk behaviors. Tobacco consumption is responsible for nearly 6 million deaths per year (World Health Organization, 2013), although it is the most preventable cause of morbidity and mortality (World Health Organization, 2013). However, the link between individual smoking behavior and individually perceived stress is not clear since research results are inconsistent – only some report a relationship between individually perceived stress and smoking (Heikkila et al., 2012; Johansson et al., 1991; Kouvonen, Kivimaki, Virtanen, Pentti & Vahtera, 2005; McKee et al., 2011), others not (Plant, Plant & Foster, 1992). Studies which found a relationship between perceived stress and smoking gathered positive results. Stressed participants were less able to resist smoking, smoked more and more intensely (increased puffs, shorter inter-puff intervals, and greater peak puff velocity), and reported greater satisfaction and reward from smoking (A. Kouvonen et al., 2005; McKee et al., 2011). However, Kouvonen et al. (2005) found these effects only applied to habitual smokers (restrictively). They smoked more and more intensively when stressed. With non-habitual smokers, stress seemed to have no effect (Heikkila et al., 2012; A. Kouvonen et al., 2005). Therefore, smoking seems to be a potent coping strategy for smokers only.

Alcohol consumption: Studies demonstrate an increase in alcohol consumption as a response to the perception of stress (Keyes, Hatzenbuehler, Grant & Hasin, 2012; Keyes, Hatzenbuehler & Hasin, 2011; Plant et al., 1992; Steptoe et al., 1998). People, who habitually drink alcohol, are more affected, than people who avoid alcohol per se (Fox, Bergquist, Gu & Sinha, 2010). Stressful life events, i.e. a divorce or job loss, increase the general alcohol consumption (frequency and amount of alcohol drank) and the risk of developing an alcohol disorder (Keyes et al., 2011). The consumption of alcohol seems to be a potential coping strategy for stressful situations, e.g. it helps to forget stress, the reasons for stress, and to calm down (Hasking, Lyvers & Carlopio, 2011). However, studies demonstrate that other variables, especially social support, are potential moderating factors for the effect of stress on the consumption of alcohol (Steptoe et al., 1998)

Drug abuse: Different studies demonstrate an increase in drug abuse in and after stressful situations and periods, however, only for people, who are addicted to drugs (Ahmadi, Karambakhsh, Mehrazmay, Salesi & NajafiManesh, 2014; Sinha, 2008). For drug experienced people an increased drug consumption may be a potential coping strategy for handling stress, although the underlying mechanisms of this association remain unclear (Sinha, 2001).

In addition, the perception of stress seems to affect the relationship between the person themselves and his or her behavior. Stress reduces resources which are necessary to maintain healthy behavior, e.g. self-regulation, self-control, or goal attainment (Muraven & Baumeister, 2000; Muraven, Tice & Baumeister, 1998).

This effect has especially been researched with respect to nutrition. Women seem to change their food consumption according to stress, especially if they are restricted eaters. Under stress, they cannot maintain their self-made food restrictions due to depleted resources (Baumeister, Bratslavsky, Muraven & Tice, 1998; Muraven & Baumeister, 2000; Muraven et al., 1998) and thus eat more sweets, snacks, and fatty fast food (Gibson, 2006; Kandiah et al., 2006; Zellner et al., 2006).

… on the environment

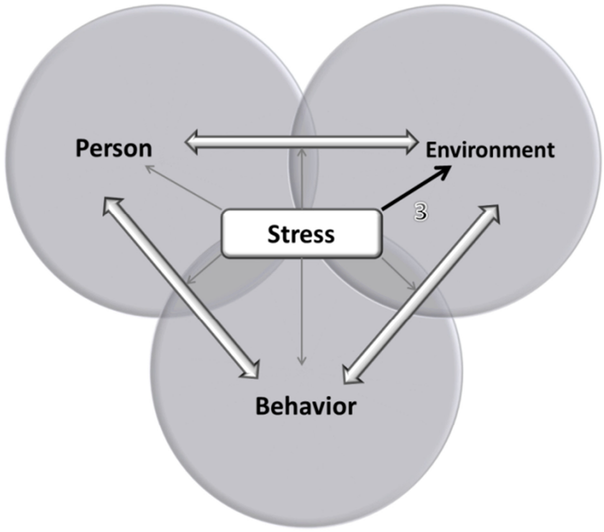

Figure 13: Effects of stress on the environment according to SCT

Very little research exists on the direct effects of individually perceived stress on the environment (Figure 13). Bandura (1989) very briefly discusses this direct effect within the Social Cognitive Theory framework. For example the appearance of a person, without being active themselves, has an effect on the social environment and may change individual behavior of other people in a direct way. In the context of stress, it is reasonable that a stressed person appears different than normal and according to this changed appearance, people within the social context change their behavior. For example, when pressed for time in the morning, getting ready, e.g. choosing the clothes you wear, your make-up or your hairstyle, will be different than when you have time to prepare. Other people in the same social context, for example work, may recognize these changes and may then behave differently (for example "oh, she is stressed, I will to myself and not disturb her today") (Bandura, 1989b; Heaney & Israel, 2008; McAlister, Perry & Parcel, 2008; Viswanath, 2008).

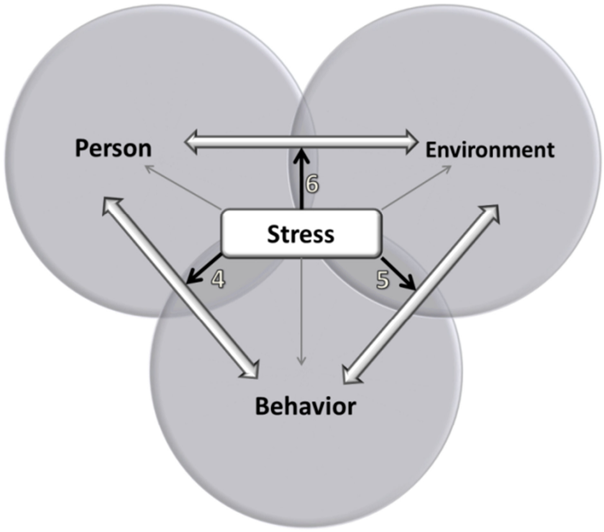

Figure 14: Indirect effects of stress according to SCT

According to this direct effect, stress may affect the environment indirectly through a changed behavior and through a change in personal elements like mood (Figure 14).

Perceived stress has been shown to affect environmental aspects related to health behavior (e.g. family food environment) (Baranowski, 1997; Bauer, Hearst, Escoto, Berge & Neumarck-Sztainer, 2012; Bevan & Reilly, 2011). Perceived stress reflected by a changed behavior results in the use of fast food for family meals and a restricted engagement in children's physical activity (e.g. not driving the children to their lessons) (Bevan & Reilly, 2011). According to these more direct results, stress may also lead to more indirect changes, like having no time for grocery shopping, which then results in the lack of fresh food for the whole family. Hence, perceived stress of one family member affects the health behavior of other family members. However, to the best of my knowledge, no other studies are available that take an inter-personal approach concerned with the direct relationships between the family members, and hence the inter-individual influences between perceived stress of one family member and the health behavior of other family members is still largely unknown.

Additionally stress has effects on the person themselves and thereby on the environment. In this line of discussion, stress has an effect on the individual mood or tension of a person, resulting in a changed interaction with environmental factors such as other family members (Almeida, Wethington & Chandler, 1999; Almeida, Wethington & McDonald, 2001; Larson & Almeida, 1999; Mroczek & Almeida, 2008). Research about tension spillover elucidates this relationship. On stressful days, people, in this study fathers, feel tension spillovers twice as likely as on unstressed days (Almeida et al., 1999). Besides direct effects of changed mood or tension resulting in stress on the environment, a change in individual behavior leads to more indirect effects; this means the perception of stress leads to a change in individual mood or tension, which causes a change in behavior, resulting in a changed interaction with the environment (Almeida et al., 2001; Repetti, 1994; Repetti, Taylor & Seeman, 2002; Repetti & Wood, 1997; Taylor, Repetti & Seeman, 1997)

It must be added, that the individual perception of stress hardly affects only one element of the person-behavior-environment interaction. Moreover, stress develops within this reciprocal interaction of the three elements and in turn affects all three elements.

Study 2 and study 3 highlight the effect of individually perceived stress on intra-individual as well as inter-individual behavior.

Study 2: Stress: personal matter or family affair?

Intra- and inter-individual relationships between stress, physical activity, sedentary behavior, and nutrition

Abstract

Individual health behavior, which is determined by individual motives, emotions and cognitive processes, is embedded in a social environment. One of the most important social environments is the family. According to Family Reciprocal Determinism, stress perceived by one family member becomes part of the family environment and may affect the interactions within the family as well as the health behavior of all family members. In this study, 214 families (mother, father, and child) were investigated with the aim of examining intra- and inter-individual relationships between perceived stress and health behavior (physical activity, leisure time sedentary behavior, and food consumption). The results indicate that individually perceived stress is related to the individual health behavior as well as the health behavior of other family members. However, these relationships vary among the family members. The inter-individual analyses revealed that this effect is strongest for the relationship of mothers' stress and other family members' health behavior. The approach of investigating the link between perceived stress and health behavior from a family perspective may be useful for understanding the relationship between stress and health.

Keywords

Family, stress, health behavior, physical activity, leisure time sedentary behavior, nutrition

Introduction

Health behavior is determined by different personal factors such as motivation, cognition and emotion. Furthermore, perceived stress is assumed to affect individual health behavior such as everyday dietary intake and physical activity (Laugero et al., 2011). Perceived stress is presumably related to unhealthy behavior. For instance, stressful situations may lead to lower levels of physical activity, more time spent on sedentary behavior, and unhealthy nutrition (Mouchacca et al., 2013). However, with regard to physical activity, literature results are inconsistent (Stults-Kolehmainen & Sinha, 2014).

According to Bandura's Social Cognitive Theory (SCT) individual behavior as well as perceptions, emotions, and motivation emerges through the reciprocal interaction between person, behavior, and environment (Bandura, 1989b). Therefore, perceived stress, which occurs through interactions between personal, behavioral, and environmental factors, could affect individual physical activity and leisure time sedentary behavior (going jogging versus watching TV) or food choice (eating fresh cooked meals versus eating fast food) as well as its environment (no fruit for the entire family because of lacking time for grocery shopping) (Bauer et al., 2012; Campbell & Crawford, 2001; Reis, Collins & Berscheid, 2000; Repetti et al., 2009). In turn, the reciprocal determinism implies that the individual and its behavior is affected by the environment and by other persons within this environment (Baranowski, 1997; Taylor, Baranowski & Sallis, 1994).

The family is the most important social context a person belongs to, with close, intensive, and long lasting interactions (Taylor et al., 1994). Therefore, the purpose of this study was to examine how perceived stress is related to a person's health behavior (particularly physical activity, leisure time sedentary behavior and food choice) and how perceived stress of one family member is related to the health behavior of other family members.

Family reciprocal determinism

Bandura's concept of a triadic reciprocal determinism (Bandura, 1989) can be expanded to the family level, referring to the model of family reciprocal determinism (Baranowski, 1997). According to this theoretical framework the individuals with their specific attributes, e.g. cognitions, motives, and behavior, are in continuous interaction with each other over a long time period and with a high frequency. The individuals and their interactions are part of a shared family environment; therefore, the family consists of individuals and the higher-level family environment. All persons influence this environment with individual attributes and in turn, while they are living in the family environment and interacting with each other they are influenced by these interactions and the environment.

Extending the SCT to the family level offers a new perspective on the link between stress and health behavior. For instance, a person's perception of stress may not only affect his own health behavior but also the family environment and through close reciprocal interactions the health behavior of other family members (McAlister et al., 2008). Consequently, a person's health behavior is not only affected by his own perceived stress but also by the perceived stress of other family members. According to the model of family reciprocal determinism, two mechanisms could be considered (Baranowski, 1997; Baranowski et al., 1996; Westman & Etzion, 2005); a) direct influences through face-to-face interactions between the family members, and b) indirect influences via the family environment. In the latter case, a family member which experiences stress can affect and alter the shared family environment, which in turn affects other family members. An example for a direct influence is a decrease in children's physical activity when parents are too busy to take the child to physical activity lessons (Bevan & Reilly, 2011) and for an indirect influence a change in the shared environment such as lack of healthy food because nobody was able to go grocery shopping (Bauer et al., 2012; Campbell & Crawford, 2001; Reis et al., 2000; Repetti et al., 2009).

Correlates of stress – individual physical activity, sedentary behavior and nutrition

According to the SCT, perceived stress and health behavior are connected on the intra-personal level. A recent review (Stults-Kolehmainen & Sinha, 2014) identified inconsistencies regarding to the effect of perceived stress on physical activity. 123 studies reported a reduction in physical activity, 29 studies an increase in physical activity and 34 studies no relationship or conflicting results regarding physical activity when individuals report stress. This inconsistency may be explained by the fact that for some people stress and a lack of time leads to less physical activity while others use physical activity as a coping strategy for managing stressful situations and regenerating lost resources through exercising after such situations.

Higher perceived stress has been related to more time spent on sedentary behavior, especially on watching TV (Johansson et al., 1991; Laugero et al., 2011; Wijndaele et al., 2007). However, to date the reason for this phenomenon has largely unknown. Laugero et al. (2011) suggested that stress may reduce the desire for physical activity and thus increase the motivation for sedentary behavior.

Healthy nutrition in relation to perceived stress can be described by choice of core foods (essential foods) and non-core foods (superfluous foods) (Johnson et al., 2011). Higher perceived stress has been associated with less frequent consumption of core foods and more frequent consumption of non-core foods (Bauer et al., 2011; Kandiah et al., 2006; Oliver & Wardle, 1999; Wardle et al., 2000). Possible explanations for these findings include the fact that time-pressure may lead to changes in the preparation of meals and that consuming a mostly non-core takeout meal saves time (Bevan & Reilly, 2011). Moreover, perceived stress may lead to reduced self-control over food choices and food quantities which mostly lead to a higher consumption of non-core foods (Groesz et al., 2011; Torres & Nowson, 2007).

Correlates of stress – physical activity, sedentary behavior, and nutrition of other persons

Perceived stress has been shown to affect environmental aspects related to health behavior (e.g. family food environment) (Bauer et al., 2012). Bevan and Reilly (2011) conducted qualitative interviews with 17 mothers during an 8 month period to capture daily challenges regarding nutrition and physical activity practices of their children. Common challenges are stress caused by lack of time resulting in the use of fast food for family meals and a restricted engagement in children's physical activity (e.g. driving to lessons); stress caused by the financial situation of the family resulted in limited budget for physical activities and healthy nutrition; and stress caused by the perceived safety of the children resulting in restricted activities outside the home. Hence, perceived stress of one family member appears to affect the health behavior of other family members. However, to the best of our knowledge, no other studies are available that take an inter-personal approach with direct relationships between the family members, and hence the inter-individual influences between perceived stress of one family member and the health behavior of other family members is still largely unknown.

While the theoretical framework of Family Reciprocal Determinism postulates reciprocal interactions between the individuals, their behavior, and their environment the presented empirical results are based on the assumption that perceived stress affects health behavior. Therefore, perceived stress is explored in this study as a predictor variable on individual health behavior, as well as health behavior of other family members.

The Present Study

We propose that including the family context in the concept of a triadic reciprocal determinism between person, behavior, and environment (Bandura, 1989b) will increase the understanding of the interrelationship between stress and health behavior. Figure 15 / S2 and Figure 16 / S2 illustrate these presumed reciprocal interactions within the family environment according to

SCT and includes the health behaviors physical activity, sedentary behavior and nutrition of the mother, the father, and the child.

The objective of this study was to research in an explorative way the intra-individual as well as the inter-individual interaction between perceived stress and health behavior within the family. Based on the reviewed literature, we hypothesized that stress perceived by an individual affects his health behavior; in particular physical activity, leisure time sedentary behavior and the consumption of core and non-core foods, and that stress perceived by one family member affect the health behavior of other family members.

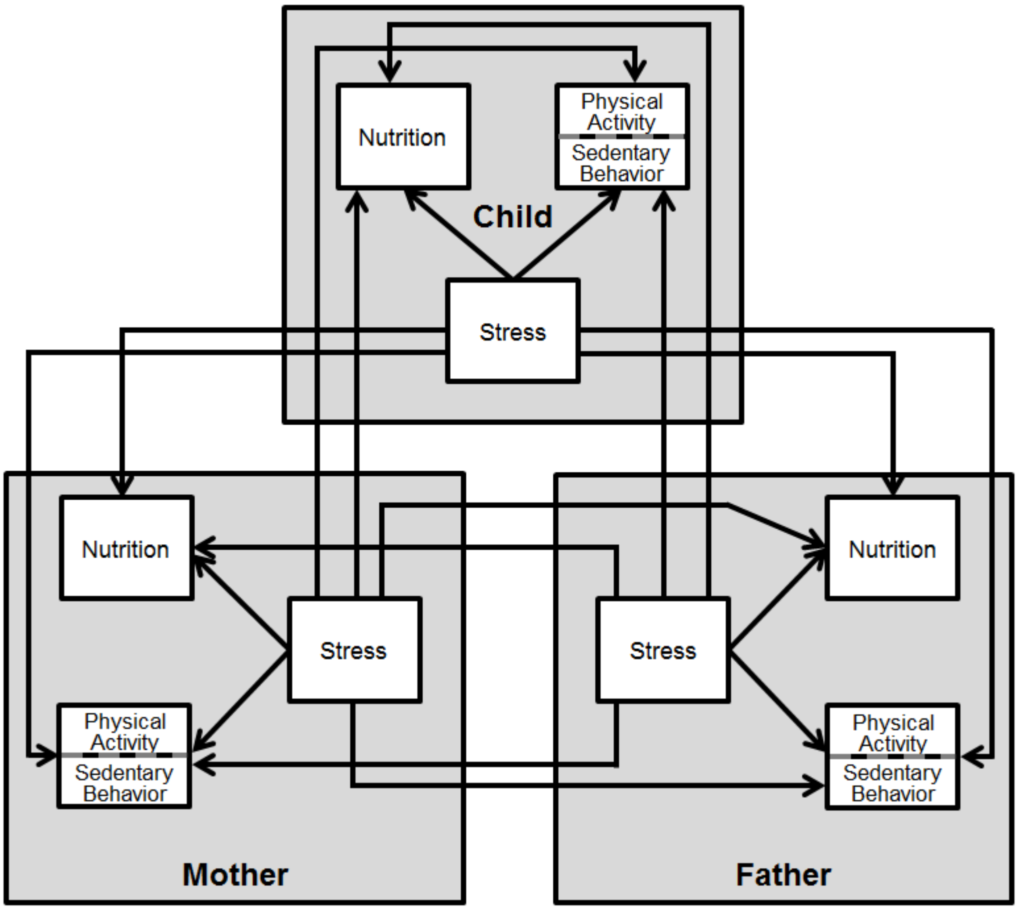

Figure 15 / S2: Schematic illustration of the questions according to Social Cognitive Theory: Intra-individual (grey boxes) and inter-individual (arrows between family members) effects between stress and health behaviors

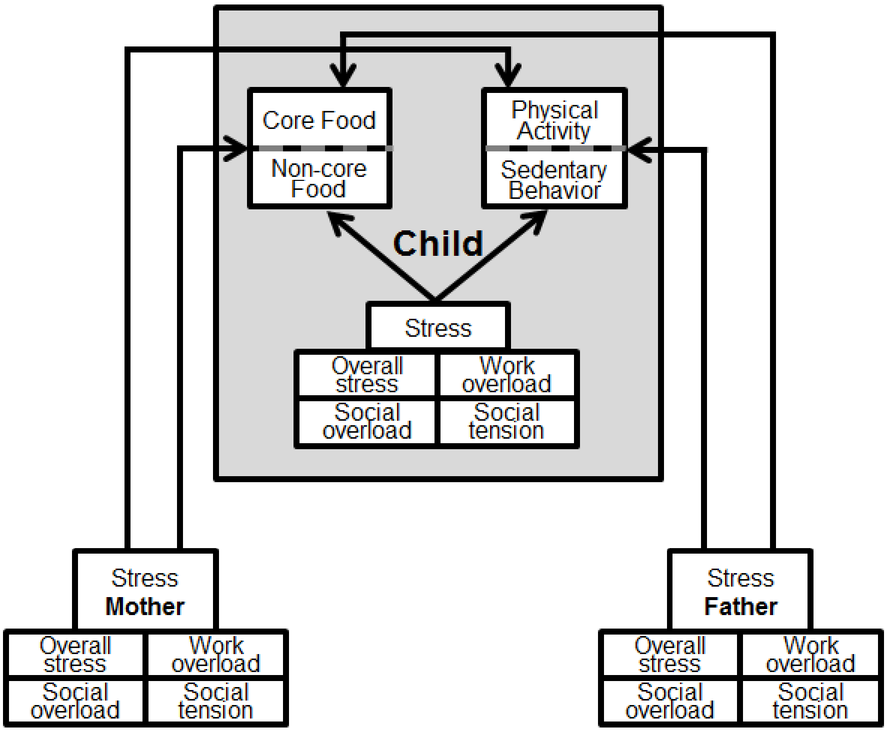

Figure 16 / S2: Exemplary schematic illustration of the intra-individual (grey box) and the inter-individual (arrows between family members) effects of stress of other family members and the health behavior of the child

Methods

Data Source

The study was conducted as a part of the multidisciplinary project "EATMOTIVE" funded by the German Federal Ministry of Education and Research. Students of 11 German secondary schools and their parents were invited to join the study Members of the research team visited the students in their classes. The students were given a short introduction on the background and the aims of the study. Furthermore, they received a set of three questionnaires – one for themselves as well as two for their parents. Additionally, the students were told that each of the family members should fill out the questionnaires by themselves. Besides the child visited during class and its parents, no other family members were considered for the survey. Of the 319 families who returned the questionnaires, all 214 two-parent families with complete sets of questionnaire were included in this study (Table 1). The excluded families were either single-parent families (n = 50) or did not return a complete set of questionnaires for all three family members (n = 55).

Written informed consent was obtained from the parents of the participating children. Participants were given detailed instructions at the distribution of the questionnaire according to the ethics guidelines of the German Psychological Society (Deutsche Gesellschaft für Psychologie & Berufsverband Deutscher Psychologinnen und Psychologen, 2005). The study protocol was agreed on by a multidisciplinary expert panel of scientists involved in the EATMOTIVE Project. The study conformed to the Declaration of Helsinki and the ethics guidelines of the German Psychological Society. All data were analyzed anonymously.

Measures

Perceived stress. Three subscales of the reliable and valid *Trierer Inventory for Chronic Stress* (TICS) (Petrowski, Paul, Albani & Brähler, 2012; Schulz, Schlotz & Becker, 2004) were used for assessing different sources of stress of parents within the preceding three months. The applied subscales are: *work overload, social overload,* and *social tension*. *Work overload* was assessed with eight items capturing stressful situations at work, e.g. 'I have too many tasks to perform'; *social overload* was assessed with six items referring to social worries and demands, e.g. 'I must frequently care for the well-being of others'; and *social tension* which assessed the perception of social conflict with six items, e.g. 'I have unnecessary conflicts with others'. All three subscale scores were summed to a total stress score of perceived chronic stress (Table 11/ S2).

The *Chronic Stress During Childhood* ('Chronischer Stress im Kindesalter'—CsiK) (Richartz, Hoffmann & Sallen, 2009) was used for assessing different sources of stress in children. The applied subscales are: *school overload, social tension,* and *lack of time. School overload* was assessed with eight items about perceived difficulties in school, e.g. 'School is difficult for me'; *social tension* which assessed the perception of social pressure due to a certain behavior in five items, e.g. 'I have conflicts with others because I speak out for myself'; and *lack of time* which assessed perceived stress due to time-related stressors in three items, e.g. 'I have too little time for friends and other hobbies'. All three subscale scores were summed to a total stress score of perceived chronic stress. All participants rated all items on a five-point Likert-Scale with respect to how often they had experienced a certain situation within the preceding three months (0 - never, 1 - rarely, 2 - sometimes, 3 - often, 4 - very often).

Table 11 / **S2:** Characteristics of perceived stress

(Sub)Scale	M	SD	Cronbach's α	Reference value	t	df	p
Mother							
Overall[g]	35.222	12.749	.93				
Work overload[a]	16.441	6.606	.93	10.000	14.163	210	<.01
Social tension[c]	6.213	3.771	.88	6.000	.853	210	.392
Social overload[b]	12.558	4.868	.84	7.800	14.098	207	<.01
Father							
Overall[g]	35.387	12.717	.92				
Work overload[a]	16.256	6.966	.94	9.600	15.395	210	<.01
Social tension[c]	5.591	3.310	.89	6.200	2.658	207	<.01
Social overload[b]	12.324	4.953	.85	7.100	15.391	210	.01
Child							
Overall[g]	19.903	7.503	.72				
School overload[d]	11.559	5.688	.71	8.700	7.019	194	<.01
Social tension[e]	5.901	3.296	.71	4.100	7.788	202	<.01
Lack of time[f]	2.373	0.947	.63	2.240	2,032	208	.04

Note: M –Mean; SD – standard deviation; study characteristics for perceived stress. Parents: a) sum of 8 items b) sum of 6 items, e.g. c) sum of 6 items d) sum of 8 items e) sum of 5 items f) sum of 3 items; g) no reference values for the sum of subscales of the Trierer Inventory for Chronic Stress.

Physical activity. Physical activity of parents and children was captured using two items. Corresponding to the guideline of the World Health Organization (2010b), the amount of days with at least 30 minutes (parents) or 60 minutes (child) of moderate-to-vigorous physical activity during a *normal week* and during the *last week* were recorded, and the mean of both scores was calculated (Prochaska, Sallis & Long, 2001). In addition, a modified version of the "Godin Leisure Time Physical Activity Questionnaire" (Godin & Shepard, 1997) was applied. The total time (minutes per week) spent on light, moderate and vigorous activities was recorded and divided by seven to calculate the average *time (minutes per day) spent on moderate and vigorous physical activity* (MVPA). The energy expenditure was calculated based on the intensity of the activities (Godin & Shepard, 1997) by multiplying the weekly frequency of vigorous, moderate and light activities with the factors nine, five and three, respectively. This value corresponds to the metabolic equivalent of tasks (METs) reflecting the energy expenditure spent on vigorous, moderate and light activities (*Weekly Activity Index*). The time per week spent on moderate and vigorous physical activities were combined. These measures of physical activity allow examining the effects of three dimensions of physical activity: overall frequency during the week reflecting the extent to which habitual physical activity is part of the individual's lifestyle (Prochaska et al., 2001); time spent on MVPA (Godin & Shepard, 1997), which is considered very beneficial for health (Dishman et al., 2004); and weekly energy expenditure (Godin & Shepard, 1997).

Sedentary time. The amount of time spent on sedentary activities was assessed by asking parents and children how much of their leisure time they spend on a typical day on the following sedentary activities: watching TV, reading books, magazines or newspapers, playing games with a computer or games console, spending time on the computer or internet, and other sedentary activities. Participants separately provided information for weekdays and weekends. *Mean daily sedentary time* and *mean media consumption time* (time spent on watching TV, playing games with computer or games console and on the computer or internet) for weekdays and weekends were calculated by adding the daily sedentary time for weekdays and weekends and dividing them by 5 days for weekdays and by 2 days for weekends, respectively.

Food Consumption. Mother, father, and child separately completed a Food Frequency Questionnaire (Winkler & Döring, 1998). On a 7-point Likert scale (0 - never to 6 - several times per day) each participant rated how often specific food items are normally consumed. The answers were recoded to calculate an index representing the frequencies of consumption during the week according to the German Nutrition Society (2013) using the following scale: 0 - never/once per month or less/several times per month; 1 - once per week; 3 - several times per week; 7 - daily; and 14 - several times per day. Ten items of the Food

Frequency Questionnaire were selected and the given ratings were summed up to a *core food index* (muesli, salad, fruits, vegetables, dairy products, fish) and a *non-core food index* (non-core foods: chocolate, sweets, cakes, salty snacks), respectively. The selection was made on the basis of the guidelines of the Australian National Health and Medical Research Council (1995). According to these guidelines core foods comprise types of foods that are part of a healthy nutrition, in contrast, non-core foods reflect an unhealthy nutrition (Bell, Kremer, Magarey & Swinburn, 2005; Johnson et al., 2011; National Health and Medical Research Council, 1995).

Educational level. Health behavior is associated with the personal educational level (Baum, Garofalo & Yali, 2006; Cutler & Lleras-Muney, 2010) and with that of other family members (Chen & Li, 2009). Therefore, it was necessary to include the personal educational level as covariate in the analyses of health behavior. Education level was assessed by asking for the highest graduation level. Considering the German tripartite school system, the categories ranged from 'no qualification' to 'university-entrance diploma' ('Abitur') and were categorized into 'low educational level' (no graduation/German 'Hauptschule'), 'medium educational level' (German 'Realschule' and lower work related graduation) and 'high educational level' (higher occupation specific graduation and German 'Gymnasium').

Data Analysis

Empirical model. Intra-individual (perceived stress and its effect on individual health behavior) and inter-individual effects (perceived stress of one person and its effect on the health behavior of another person) were analyzed using multivariate linear regression models. All analyses were controlled for the educational levels of the mother and father by including the educational levels as covariates in the multivariate linear regression models. Statistical analyses were performed in SPSS for Windows version 21.0. Statistically significant results were based on the standardized beta-coefficients of the multivariate linear regression models. The significance levels for all statistical tests were set to .05 (*) and .01 (**). Results with p-values below .10 ($^{+}$) were interpreted as nearly significant results.

Results

Perceived stress

The largest stress contributors in children and parents were school and work overload, respectively (Table 12 / S2). Mothers, fathers, and children perceived significantly more stress in all subscales than the reference group (Table 1) (Petrowski et al., 2012; Richartz et al., 2009). Children with lower educational level reported more overall stress and stress due to school overload and lack of time than children with medium or high educational level (overall stress: M_{low}=24.7; SD_{low}=8.1; M_{medium}=21.3; SD_{medium}=7.2; M_{high}=19.2; SD_{high}=7.1; $F_{(2,175)}$=5.8; p<.001; stress due to school overload: M_{low}=14.6; SD_{low}=5.5; M_{medium}=13.1; SD_{medium}=6.0; M_{high}=11.1; SD_{high}=5.4; $F_{(2,179)}$=5.1; p < .001; stress due to lack of time: M_{low}=2.5; SD_{low}=1.2; M_{medium}=2.0; SD_{medium}=1.0; M_{high}=2.4; SD_{high}=0.9; $F_{(2,192)}$=3.1; p = .053).

Health behavior

Only 7.5% of the children, 20.1% of the fathers, and 22.3% of the mothers met the WHO guidelines of at least 30 minutes activity per day for adults and at least 60 minutes activity per day on at least most days during the week (World Health Organization, 2010b) (Table 2). Children spent 45 minutes, mothers 31 minutes, and fathers 36 minutes on MVPA (Table 2). Children spent approximately 5 hours per day on sedentary activities after school on weekdays and at least 7.5 hours per day on the weekend. Media consumption (TV, PC, internet, and games consoles) accounted for the largest amount of sedentary activities. These sedentary times meet the German subsample of the Health Behavior in School-aged Children Study 2009/2010 (HBSC Team Germany, 2011a, 2011b; Kolip, Klocke, Melzer & Ravens-Sieberer, 2013). In contrast, parents spent about 3 hours per day on sedentary activities on weekdays and 4 hours per day on weekends. Time spent with media consumption was lower for parents than for children; however, fathers spent more time with media than mothers. Children consumed more non-core food than their mothers and fathers. However, most families ate core-food at least several times a week or even on a daily basis.

Health behaviors, especially time spent on sedentary activities, were associated with the educational level – persons with higher educational level behave slightly healthier (more physical activity, less sedentary time and a more frequent consumption of core food (data not shown).

Table 12 / **S2:** Descriptive statistics (M and SD) of the subject characteristics

Category	**Subcategory**	**Child**		**Mother**		**Father**	
		M	**SD**	**M**	**SD**	**M**	**SD**
Age	**girls (n=126)**	14.1	1.4	45.0	4.4	47.7	6.9
	boys (n=85)	14.5	1.9				
Educational level	**low**	12.2%		17.8%		24.4%	
	medium	14.2%		41.1%		18.8%	
	high	73.6%		41.1%		56.8%	
Working status	**full-time**			15.5%		89.3%	
	part-time			67.6% M=19.8h SD=7.0h		2.8% M=22.0h SD=8.1h	
	not working			16.9%		7.9%	
Physical activity							
Frequency during the week (days/week)		3.9	1.6	4.4	2.0	4.7	2.1
Time with MVPA (min/day)		45.1	31.8	31.1	29.9	36.2	48.4
Weekly Activity Index (MET)		51.1	26.1	44.9	24.2	45.3	25.5
Leisure time sedentary behavior (min/day)							
Time with sedentary behavior weekday		297.9	216.3	184.2	120.6	187.6	116.8
Time with sedentary behavior - weekend		450.7	369.5	239.6	142.1	252.4	137.5
Media consumption - weekday		174.8	164.4	109.9	111.2	120.3	105.9
Media consumption - weekend		276.8	316.1	133.8	117.7	157.6	108.0
Nutrition (average servings/day)							
Core food		17.1	9.2	19.0	8.2	15.2	8.3
Non-core food		9.6	9.7	7.1	7.2	7.5	7.6

Note: M – mean; SD – standard deviation; possible scores: Physical activity: frequency during the week (days/week) 0 to 7 days. Media consumption on weekdays and weekends: TV, PC/internet, computer/console games. Nutrition: frequency of consumption of core food (salad, vegetables, fruit, muesli, dairy and fish; average servings/week), frequency of consumption of non-core food (chocolate, cake, salty snacks, sweets; average servings / week).

Intra-individual effects of perceived stress on physical activity, sedentary behavior, and nutrition

Children. In children, physical activity was not related to the overall perceived stress (Table 13 / S2). However, children spent less time on moderate-to-vigorous activities if they were stressed due to school overload (Table 14 / S2). Further, more overall stress went along with more time spent on sedentary activities and with media on weekdays (Table 13 / S2). While higher stress due to school overload was associated with higher media consumption on weekdays, stress due to lack of time reduced the time spent with sedentary activities and media consumption on weekends (Table 14 / S2). The perceived stress of children was not related to the consumption of core and non-core food (Table 13 / S2; Table 14 / S2).

Mothers. Overall, perceived stress of mothers did not affect their physical activity behavior or their consumption of core and no-core food (Table 13 / S2, Table 14 / S2). However, if the mother was more stressed due to work overload and social tension, she consumed core foods less frequently. In contrast, in the case of stress due to work overload, she consumed more frequently non-core foods. In contrast, when she was stressed due to social tension, she ate less frequent core foods (Table 14 / S2).

Fathers. Perceived stress was not associated with physical activity; however, the father spent less time on sedentary behavior on weekdays, when he was stressed due to work overload (Table 13 / S2). Similar to the results for mothers, the father consumes less core foods if he is stressed due to work overload, however, he does not consume more non-core foods. He consumed more often non-core foods, if he was stressed due to social overload (Table 14 /S2).

Inter-individual effects of perceived stress on physical activity, sedentary behavior, and nutrition

Child. The child was less frequently physical active and had a lower weekly activity index, if the mother perceived higher overall stress (Table 13 / S2) and more stress due to work overload (Table 14 / S2). In contrast, only higher stress due to work overload of the father was associated with more frequent physical activity of the child (Table 13 /S2). Moreover, the child spent more time on sedentary behavior on weekdays, if the mother was stressed due to social overload. The more overall stress the mother perceived, the less core foods and the more non-core foods the child consumed (Table 13 / S2).

Mother. Perceived stress of the child and the father did not significantly affect physical activity or nutrition of the mother. The more stress overall (Table 3) and due to school overload (Table 14 / S2) the child perceived, the more time the mother spent on sedentary behavior on weekdays and weekends. In contrast, higher perceived stress overall (Table 13 / S2) and due to work overload (Table 14 /S2) of the father went along with lower sedentary time on weekends and lower media consumption on weekdays and weekends of the mother.

Father. Perceived stress of the child and the mother did not significantly affect physical activity of the father. However, the father spent more time on sedentary behavior and with media on weekdays and weekends, if the child was stressed overall (Table 13 / S2) and due to school overload (Table 14 / S2). In contrast, when the mother perceived more stress due to social tension, the father spent less time with media on weekdays (Table 14 / S2). Moreover, higher perceived overall stress (Table 13 / S2) and stress due to work overload (Table 14 / S2) of the mother was associated with lower consumption of core foods of the father.

Table 13 / S2: Effects of perceived stress (overall) on health behaviors - multivariate linear regression analyses

Variable	Person	Overall perceived stress			Model values	
		Child	Mother	Father	F	R^2
Physical activity						
Frequency during the week (days/week)	Child	-.066	**-.256****	.094	2.371*	.042
	Mother	-.034	.001	.149	.861	.026
	Father	-.060	-.010	-.132	.755	.023
Time with MVPA (min/day)	Child	-.023	-.133	.131	1.273	.009
	Mother	.024	-.141	.085	.622	.026
	Father	-.074	-.009	.097	1.014	.040
Weekly Activity Index (MET)	Child	.002	**-.259****	.057	1.991	.037
	Mother	-.015	-.001	.011	.196	.009
	Father	-.089	.059	-.032	.253	.012
Leisure time sedentary behavior (min/day)						
Time with sedentary behavior - weekday	Child	**.181***	.138^{+}	-.005	2.822*	.051
	Mother	**.226****	.056	-.049	2.124*	.033
	Father	**.246****	-.031	-.120	6.363**	.137
Time with sedentary behavior - weekend	Child	.040	.019	.011	.853	.025
	Mother	**.212****	.001	-.117^{+}	2.282*	.037
	Father	**.164***	-.023	-.041	3.531**	.070
Media consumption – weekday	Child	**.158***	.102	.022	2.991*	.056
	Mother	.149^{+}	.106	**-.127***	1.744	.022
	Father	**.295****	-.009	-.054	6.901**	.149
Media consumption – weekend	Child	-.012	-.047	.034	1.792	.023
	Mother	.154^{+}	.128	**-.163***	2.525*	.043
	Father	**.189****	-.001	-.040	5.093**	.108
Nutrition (average servings/week)						
Core foods	Child	-.034	**-.135***	-.007	1.571	.017
	Mother	-.079	-.118	.085	4.110**	.086
	Father	-.001	**-.194***	-.012	2.053	.031
Non-core foods	Child	.097	.131^{+}	-.029	1.031	.031
	Mother	.025	.072	-.023	.604	.012
	Father	.019	-.080	.084	1.765	.022

Note: Multivariate linear regression analyses of the effect of overall perceived stress on health behaviors. Standardized beta coefficients; significance levels: $^{+}p < .10$ *p < .05; **p < .01; model values: df = 6; covariate: all results were controlled for personal education level of mothers and fathers.

Table 14 / S2: Effects of perceived stress (different sources of stress) on health behaviors - multivariate linear regression analyses

Variable	Person	Child: School over-load	Child: Social tensio n	Child: Lack of time	Mother: Work over-load	Mother: Social over-load	Mother: Social tension	Father: Work over-load	Father: Social over-load	Father: Social tension	Model values: F	Model values: R²
Physical activity												
Frequency during the week (days/week)	Child	-.068	.023	.001	**-.223***	-.068	.026	**.218***	-.127	-.026	1.28	.019
	Mother	.049	-.099	.131	-.171	.149	.088	.157	-.078	.088	1.29	.018
	Father	-.127	.081	**.228****	-.003	.031	.019	-.120	.021	-.021	1.32	.021
Time with MVPA (min/day)	Child	**-.102***	.107	-.045	-.137$^+$	-.014	-.066	.112	-.072	.153	1.14	.010
	Mother	.034	-.017	.005	.126	-.143	-.184$^+$	-.165	.247$^+$	.057	.809	.074
	Father	-.045	-.003	.127	-.042	.070	-.013	.202	-.090	.028	.819	.070
Weekly Activity Index (MET)	Child	-.045	.080	-.034	**-.300***	.026	-.019	.140	-.078	-.019	1.11	.010
	Mother	-.067	.047	-.075	-.176	.190	-.035	-.063	.088	-.049	.377	.039
	Father	-.156	.104	.053	-.054	-.008	.134	.123	-.130	-.041	.445	.048
Leisure time sedentary behavior (min/day)												
Time with sedentary behavior (day)	Child	.134	.098	.003	.023	**.241***	-.124	-.019	.014	-.006	1.99*	.060
	Mother	**.269****	-.029	-.049	-.155$^+$	.189$^+$	.021	-.022	-.099	.047	1.62	.039
	Father	**.161***	.116	-.079	-.015	.040	-.116	**-.240***	.078	.161	3.38*	.133
Time with sedentary behavior (end)	Child	.031	.032	**-.172***	.058	.029	-.122	.058	-.073	.020	1.18	.012
	Mother	**.245****	-.020	-.147$^+$	-.100$^+$	.138	-.056	**-.124***	.000	-.045	1.95*	.058
	Father	**.215****	-.058	-.075	-.079	.088	-.063	-.048	.004	-.025	2.01*	.061
Media consumption (day)	Child	**.159***	.037	-.018	.011	.151	-.025	-.039	.000	.053	1.71	.044
	Mother	.139	.021	-.015	-.033	.103	.053	**-.132***	.047	-.093	.953	.061
	Father	**.209****	.139	.019	-.022	.150	**-.198***	-.124	-.016	.147	3.81*	.153
Media consumption (end)	Child	.003	.012	**-.167***	.055	-.057	-.088	.051	-.084	.070	1.38	.024
	Mother	.152$^+$	.012	-.036	.043	.047	.063	**-.128***	.035	-.139	1.13	.025
	Father	**.261****	-.073	.017	-.028	.143	-.140	-.084	-.004	.059	2.99*	.114
Nutrition (average servings/day)												
Core food	Child	-.056	.030	.084	.019	-.104	-.095	.116	-.010	-.132	1.31	.020
	Mother	-.051	-.049	-.016	**-.243***	**.244***	**-.176***	-.101	.199$^+$	-.006	3.07*	.119
	Father	-.008	-.026	-.024	**-.263***	.116	-.077	**-.236***	**.243***	-.016	1.95*	.060
Non-core food	Child	-.079	.256	.009	-.185$^+$	**.300****	.081	-.094	.085	-.061	2.32*	.080
	Mother	-.022	.074	.020	**.317****	**-.287***	.050	.174	-.091	-.137	1.76	.047
	Father	.026	-.002	-.070	.007	-.076	-.043	.061	-.025	.067	.912	.059

Note: Multivariate linear regression analyses of perceived stress because of school/work overload (child / parents), social tension (child and parents), social overload (parents) or lack of time (child) on health behaviors. Standardized beta coefficients; significance levels: $^+p < .10$ *p < .05; **p < .01; model values: df = 6; covariate: all results were controlled for personal education level of mothers and fathers.

Discussion

The objective of this study was to explore if individual perceived stress is related health behavior of the other family members. Based on the Model of Family Reciprocal Determinism it was assumed that individual perceived stress affects the interactions with others and the shared family environment and therefore is related to the health behavior of other family members. The results of this study support the assumption that there are intra- as well as inter-individual relationships between perceived stress and health behavior.

Intra-individual effects of perceived stress on physical activity, sedentary behavior, and nutrition

In agreement with previous studies (Bevan & Reilly, 2011; Johansson et al., 1991; Michels et al., 2012; Wallis & Hetherington, 2009; Wardle et al., 2000), perceived stress affected the time spent on sedentary behavior and the consumption of core and non-core food for all family members. The effects of individually perceived stress on the different health behaviors varied between family members and with regard to the sources of stress. Greater stress due to work overload was associated with less time spent on sedentary activities and especially media consumption for all family members. It has been shown that time spent with sedentary behavior increase the risk for developing overweight and obesity, certain coronary heart diseases (Chomistek et al., 2013) and diabetes mellitus Type 2 (Proper, Singh, Van Mechelen & Chinapaw, 2011). These ‘positive’ health effects (reduction of sedentary time) may be caused by longer working hours away from home. In contrast, greater stress due to social overload was associated with slightly more time spent on sedentary activities during weekdays for mothers. Sedentary activities such as watching TV has been discussed as a coping strategy for recharging depleted resources (Heikkilä et al., 2013; Park & Iacocca, 2013). Hence, more time spent on sedentary activities could be a way of coping with stress (Baumeister et al., 1998).

Overall perceived stress was not related to either mothers' or fathers' nutrition, which is not in agreement with results of other studies (Zellner et al., 2006; Zellner, Saito & Gonzales, 2007). For instance, Zellner et al. (2006) reported gender differences according to the consumption of core and non-core foods during and after stressful situations. Dietary restrained eating, which is mostly found in women, plays an important role (Wardle et al., 2004; Zellner et al., 2006). Especially women who report to be dietary restrained eaters presumably react with an overeating of non-core foods during and after stressful situations because of a loss of self-control under stress (Wardle et al., 2004; Zellner et al., 2006). In contrast, men do not seem to change their consumption of core and non-core foods when they perceive stress (Zellner et al., 2007). Considering the different sources of stress shows a different picture: stress due to work overload was associated with lower and stress due to social overload with more frequent consumption of core foods for both parents. Opposite effects were found for non-core foods, for mothers, higher perceived stress due to work overload was associated with a more frequent and stress due to social overload with a less frequent consumption of non-core foods. These relationships may be caused by a lack of time due to work overload and longer working hours resulting in less time and lower motivation for preparing healthy meals (Bevan & Reilly, 2011). Other studies have indicated that work stress leads to fewer whole meals and more frequent snacking during working times (Bevan & Reilly, 2011; Oliver & Wardle, 1999; Tryon et al., 2013; Wallis & Hetherington, 2009).

In our study, perceived overall stress did not affect physical activity in any of the family members, which is in agreement with results of the review by Stults-Kolehmainen and Sinha (2014). In contrast, other studies have indicated that greater perceived stress is related to less time spent on physical activity (Aldana et al., 1996; Anne Kouvonen et al., 2005; Kouvonen et al., 2013; Laugero et al., 2011; Ng & Jeffrey, 2003). To date, the mechanism of how specific aspects of individually perceived stress are linked to individual health behavior is poorly understood. One possible pathway are depleted individual resources in stressful situations (Muraven & Baumeister, 2000) leading to compromised strength for subsequent self-control for being physically active or resisting eating non-core foods. Watching TV or consuming non-core foods are activities that require less self-control and may be a coping strategy to recharge the individual's resources (Steptoe, 2007b). However, physical activity has also been discussed as a possible coping strategy (Azizi, 2011; Balantekin & Roemmich, 2012; Rostad & Long, 1996). The standard deviations in parameters describing health behavior were very large indicating large individual differences between persons. Reactions to stressful situations presumably vary between persons, and hence it is feasible that one person uses physical activity as a coping strategy for stress while another person uses leisure time sedentary behavior as a coping strategy (Azizi, 2011). A similar phenomenon of person-specific changes in eating behavior with perceived stress - overeating or undereating appears during or after stressful situations or periods (Balantekin & Roemmich, 2012; Oliver & Wardle, 1999; Roemmich, Lambiase, Lobarinas & Balantekin, 2011). Further research integrating individual coping strategies is necessary to clarify the relationship between perceived stress and health behavior. Moreover, the results emphasize the importance of considering different sources of stress.

Inter-individual effects of perceived stress on physical activity, sedentary behavior, and nutrition

In this study, we also considered how perceived stress of one family member may affect the health behavior of another family member. Based on the results of this study three main aspects of this interrelationship could be identified: the important role of the mother, the parent dyad and the role of the child.

The important role of the mother. Perceived stress of the mother affected the health behavior (especially physical activity and the consumption of core and non-core foods) of the other family members and mainly that of the child. According to the literature, the mother is mostly responsible for health-related behavior within the family: Preparing family meals or going grocery shopping is commonly the duty of mothers (Bevan & Reilly, 2011; Devine et al., 2003;

Tinsley, 1997) and mothers seem to act as guard to protect and advise on healthy living (Beets, Cardinal & Alderman, 2010). Currently, this role seems to be predominantly even, if it is more and more common that mothers work away from home (Bauer et al., 2012; Beagan, Chapman, D'Sylva & Bassett, 2008; Jabs et al., 2007; Lake et al., 2006). Hence, individually perceived stress of mothers could affect the intra-familial interactions and organizational arrangements, e.g. driving children to activity lessons, going grocery shopping and preparing meals. Bevan and Reilly (2011) postulated that lack of time is one of the most serious barriers mothers have to overcome. It appears likely that mothers, especially if they are working, experience an overload of tasks to manage the daily family life (Lundberg & Frankenhaeuser, 1999). The resulting lack of time could be a contributor to the negative association between perceived stress and health behavior within the family. To overcome these problems, a more effective compatibility of family and career for working mothers and a more effective division of responsibilities and housework between the parents seems warranted (Martín-Fernández, de los Ríos, Cazorla & Martínez-Falero, 2009).

The parent dyad. The results of our study indicate that the perceived stress of one parent affect the other parent’s behavior especially regarding leisure time sedentary behavior. For instance, higher perceived stress of the father is associated with less time spent on sedentary behavior on weekends and with media on weekdays and weekends of the mother. Domestic division of housework could be responsible for these effects (Beagan et al., 2008). Perceived stress of fathers mostly correlates with more time spent working away from home and a greater work-family conflict (Adkins & Premeaux, 2012; Beaujot & Andersen, 2007). More time spent away from home inhibits an adequate division of housework among both parents and consequently one partner, in this case the mother, has to perform the family related tasks the other partner, here the father, is not able to do (Baxter, 2000). In turn, having to complete more tasks leads to a lack of time (e.g. no time for leisure time sedentary behavior or other things), resulting in higher perceived stress of mothers, (Bevan & Reilly, 2011), which fits the framework of Family Reciprocal Determinism.

The role of the child. Greater perceived overall stress and stress due to school overload of the child was associated with more sedentary behavior of both parents. There are several possible reasons for this relationship. Time spent on sedentary behavior includes time spent on diverse inactive behaviors such as sitting or reading. Hence, a possible reason for the longer time spent on sedentary behavior of the mother could be that she supports the child in doing homework or studying with the child (Hoover-Dempsy et al., 2001). Interestingly, greater perceived stress due to school overload of the child was associated with more time spent with media on weekdays and weekends of the father. There is no obvious explanation for this phenomenon, and it is possible that other parameters such as the educational level account for this relationship. Health behaviors and perception of stress were related to the educational level of the family members. For instance, the descriptive results of this study indicated that the child's perceived stress is related to the school type attended. The educational level of the child was in turn related to the educational level of the parents: the higher the educational level of the parents, the higher the educational level of the child. Furthermore, the lower the educational level of the person, the more time the person spent with sedentary behavior and with media. Hence, it seems feasible that educational level acts as moderator of the intra-individual relationship between perceived stress and health behavior. Further research is warranted on the family itself, the processes within the family system and the effects of one family member on the family system taking the educational level into account.

This is consistent with findings that emphasize that the family is an important social environmental context that shapes the individual's health behavior (Ball & Timperio, 2006; LaGuardia & Patrick, 2014). Therefore, taking into account such an inter-individual perspective could enrich research in the health behavior context.

Limitations and Conclusions

In this study, we assumed one direction of influence. However, the theoretical framework implies reciprocal interactions. The other direction, health behavior affecting perceived stress, may be thinkable as well. To verify directions, longitudinal studies with a cross-lagged-panel design would be necessary.

Parents and children report significantly more stress in all subscales than the scale specific reference groups. Different reasons might be responsible: the reference values are from year 2003 for parents and 2009 for children; the significant differences in the stress report indicate a change in the perception of stress during the last years. For parents, stress seems to have increased during the last years (Cohen & Janicki-Deverts, 2012). For children the increase in the perception of stress may be a result of school reforms in the German school system. Perceived stress and health behavior were considered as stable parameters. However, these variables may change depending on the specific boundary conditions and thus it would be interesting to investigate intra-individual short-term variations in stress perception and their effects on health behavior, for instance, in a day-to-day diary study.

The relationship between one person's perceived stress and someone else's health behavior is more complex than assumed in this study (De Vriendt, Moreno & De Henauw, 2009). Including individual (e.g. individual habits, attitudes) and family level mediators and moderators, e.g. Family Health Climate, (Niermann et al., 2014) would be beneficial to further investigate this new perspective of linking perceived stress with family environment and health behavior of other family members.

To the best of our knowledge, this is the first study which linked perceived stress with health behavior on the individual level as well as between different individuals within a family. Bandura's Social Cognitive Theory (Bandura, 1989b) and its expansion to the family level by Baranowski (1997) and Taylor, Baranowski, and Sallis (1994) represents a useful theoretical framework for describing those inter-individual relationships between stress and health behavior within a family. Further research within this framework is necessary to get more insight in the interactions between individuals and environment and the development of a testable theoretic model.

The results of our study indicate that individually perceived stress is related to individual health behavior as well as the health behavior of other family members. Furthermore, the results emphasize the importance of distinguishing between different health behaviors (core and non-core food consumption, physical activity and sedentary behavior) and between different sources of stress (family, work, personal conflicts). The consideration of the family environment, including other family members, enriches previous results and adds a new perspective on the link between stress and health behavior. More insight in the interaction between individuals and their shared environment are important for the development of intervention programs. Especially interventions which aim to improve the health behavior of children and adolescents should integrate the family and should aim to improve family level variables such as the Family Health Climate (Niermann et al., 2014).

Study 3: On the move or on standby?

A day-level study on the effects of stress on physical activity

Abstract

Background

According to Bandura's reciprocal determinism between person, behavior, and environment individual perceived stress is related to individuals' health behavior. However, the direction of this relationship remains unclear – physical activity and perceived stress may be positively, negatively, or not related. In line, literature results concerning the effect of perceived stress on physical activity show inconsistent findings – perceived stress can have negative, positive or no relationships on physical activity (Stults-Kolehmainen & Sinha, 2014). Reasons for these inconsistent findings could be differences between definition and assessment of perceived stress and physical activity. In addition perceived stress and physical activity are fluctuating variables; they may be related on the day level but maybe not over weeks or months. Finally, individual reactions to perceived stress could be quite different (Coulter, Dickman & Maradiegue, 2009). A diary study with time-varying predictors and outcome variables may clarify individual effects of stress on physical activity and the differences between stressful and non-stressful days.

Method

In a dairy study, 31 men and 61 women (M_{age}=45.22 years; SD=8.01) were asked about their stress on seven consecutive days. Physical activity (energy expenditure during leisure time) was measured by an accelerometer (Actigraph GT3$^{©}$). Multilevel regression models with time-varying predictors and outcome variables were calculated to detect within-person effects in the longitudinal data. Additionally, the individual energy expenditure on stressful and non-stressful days was descriptively compared and individual within-person regression coefficients were calculated.

Results

The models show neither a within-person (Estimate = 5.11, SE = 6.41) nor a between-person (Estimate = 6.86; SE = 9.27) effect of daily perceived stress on daily energy expenditure during leisure time. However, the individual comparison of the energy expenditure on the most stressful and least stressful days, as well as the mean energy expenditure on more stressful and on less stressful than personal weekly mean days, show individually different processes. Three groups could be identified: Reducers (n=37; $Mean_{Estimate}$=-57.07) lower their energy expenditure in mean of 340.38 kcal on highly stressful days, compared to least stressful days; Increasers (n=34; $Mean_{Estimate}$=59.25) raise their energy expenditure in mean of about 382.62 kcal on highly stressful days, compared to least stressful days, and Maintainers (n=20; $Mean_{Estimate}$=-.90) do not change their energy expenditure.

Conclusion

The individual analyses on a daily level clarified that people react individually to perceived stress. This individual reaction may be the cause of the inconsistent literature results. In further studies these individual differences should be taken into account. In addition potential mediators and moderators should be examined.

Keywords

Diary study, multilevel regression model, stress, physical activity, energy expenditure

Introduction

According to the reciprocal determinism between person, behavior, and environment (Bandura, 1989b), an interaction between perceived stress and individual health behavior exists. On the one hand, the perception of stress is a result of interactions between the person, one's environment, and her/his behavior. On the other hand, perceived stress affects each dimension and the reciprocal interactions in the model (McAlister et al., 2008). Therefore, it could be assumed that individually perceived stress affects individual health behaviors such as physical activity or the consumption of a healthful diet. However, a recent review found inconsistent results; most of the reviewed studies indicate a positive relationship, some a negative, others no relationship between perceived stress and physical activity (Stults-Kolehmainen & Sinha, 2014).

Theoretical Background: Social Cognitive Theory and the perception of stress

Personal factors, characteristics of the environment and individual behavior comprise an interacting framework for functioning in daily life (Bandura, 2001). Demands within this framework, regardless of whether internal to the person, e.g. worries about the job, or external, e.g. job demands or time pressure, may affect interactions within the framework (McAlister et al., 2008). In the case that demands exceed existing resources, be it internal (e.g. self-efficacy or self-confidence), or external (e.g. social support), the appraisal of the situation results in the perception of stress (Lazarus & Launier, 1978). In turn personal factors, e.g. self-efficacy (Schwarzer & Renner, 2000), his behavior, e.g. health behaviors such as physical activity, sedentary behavior, or nutrition (Lundahl et al., 2013), and the environment, e.g. job performance (Meijman & Mulder, 1998), may be affected by the perception of stress and the individuals' efforts to cope with it (Bandura, 1989b; Baranowski et al., 1996; Folkman & Moskowitz, 2004). Moreover, on the one hand, the perception of stress is a very *individual* one*;* the appraisal of situations depends on individual resources which lead to an individual perception of stress (Lazarus & Folkman, 1986). On the other hand, the same amount of stress, e.g. conflict with the partner or job demands, may have very individual effects on the daily activity, depending on the personality and habitual behavior of each person (Coulter et al., 2009; Laugero et al., 2011).

Empirical Background: stress and health behavior

Perceived stress is associated with a variety of health behaviors, e.g. physical activity, sedentary behavior, or nutrition (Ng & Jeffrey, 2003). Overall, these behaviors appear to change towards an unhealthy lifestyle (Heikkilä et al., 2013), however, the literature reports inconsistent findings. With regard to nutrition, an increase in the consumption of energy-dense food and snacks (Michels et al., 2012; Sproesser, Schupp & Renner, 2014; Tryon et al., 2013), and a decrease in the consumption of healthy foods is apparent (Habhab, Sheldon & Loeb, 2009). Nevertheless, some studies report differences in the amount of food consumed – some people eat more when stressed, others less (Oliver & Wardle, 1999; Sproesser et al., 2014), especially in combination with individual factors, e.g. being a restrained eater (Wallis & Hetherington, 2009; Wardle et al., 2000). Women particularly seem to modify their nutrition behavior when stressed (Zellner et al., 2006; Zellner et al., 2007). In terms of sedentary behavior, studies show an increase of time spent with sedentary behavior, like watching TV, when experiencing stress (Balantekin & Roemmich, 2012). When it comes to smoking, alcohol, and drug abuse, there is empirical evidence for an increase in smoking (A. Kouvonen et al., 2005) and higher consumption of alcohol and drugs when stressed (Payne, Kinman & Jones, 2012; Plant et al., 1992). However, looking at physical activity, a review on the effects of perceived stress on physical activity and exercise found inconsistent results. Stults-Kolehmainen and Sinha (2014) analyzed 168 studies on the effects of perceived stress on physical activity and exercise. 79.8% (n=152) of the analyzed studies support the hypothesis that stress has effects on physical activity and exercise. Of these 152 studies, most (n=123) report a negative effect, i.e. a reduction of physical activity and exercise during and after stressful situations. In contrast, 29 studies found the opposite trend – an increase of physical activity and exercise. In the remaining 34 studies, no relationships or conflicting results were found.

Stults-Kolehmainen and Sinha (2014) described several limitations in the literature examining associations of stress and physical activity. For instance, studies included in their analysis differed in their *definition* and *measurement* of stress and physical activity. Some studies define and operationalize stress as family and daily life conflicts, others take job strains and demands into consideration, a third group refers to stress as cumulative daily hassles, or major life events. Additionally, the operationalization of physical activity is very diverse; physical activity could be operationalized through the frequency of exercise sessions, the number of active time frames over a given time period, the energy expenditure during exercise sessions or across daily activities. Furthermore, both perceived stress and physical activity are time-varying factors and perhaps there is a relationship evident on the day level but not over weeks or months. Additionally, in most studies the time frame of stress and physical activity differs, e.g. the perception of stress is assessed for the last month or year, whereas physical activity is measured in only the last week. It is assumed that individual perceived stress and physical activity are related with each other on a daily level, however not over weeks or months. Additionally it is assumed that people *react individually* to stress, this means some people may increase, while others decrease or do not change their physical activity level. These limitations may be the cause the found literature results of Stults-Kolehmainen and Sinha.

To overcome these described problems, diary study designs combined with more objective measurements of daily activity are necessary to gain further insight into the stress-behavior-relationship.

Therefore, the aim of this paper is to investigate the effects of perceived stress on energy expenditure during leisure time from an individual perspective by taking into account the fluctuation of perceived stress and physical activity with a diary study design. The following questions are addressed:

(1) Do people change their physical activity during leisure time on more stressful days compared less stressful days – or more precisely: do we have a within-person effect of daily perceived stress on daily energy expenditure during leisure time?

(2) To what extend do people differ from each other with regard to their energy expenditure on stressful and non-stressful days?

Methods

The study was conducted as a part of the multidisciplinary project *EATMOTIVE* which is funded by the German Federal Ministry of Education and Research. Within this diary study the participants were asked about time-varying variables like daily physical activity, sedentary behavior, nutrition, mood, daily hassles and conflicts, and family life on a day level. Additionally, all participants wore an accelerometer to objectively measure their daily activity. Time-invariant variables, like self-efficacy with regard to physical activity and healthy nutrition, family health climate, socioeconomic and personality variables were assessed before the diary week.

Study sample

Thirty-one men with a mean age of 43.6 years (SD = 10.66) and sixty-one women with a mean age of 46.2 years (SD = 6.22) living in the area of Konstanz, Germany, took part in the study. All participants were part time or full time employed (mean working hours per week: M = 21.89; SD = 7.07). The participants were recruited through the "Konstanzer Life Study" (Renner, Sprösser, Klusmann & Schupp, 2012), the university employees, or during local events in the area of Konstanz.

Diary protocol

All participants were tracked for seven consecutive days, starting on a Wednesday to capture the weekend in the middle of the researched days (Bolger, Davis & Rafaeli, 2003). Every participant received a smartphone (Samsung GT-I9001) to fill out daily questionnaires and an accelerometer (ActiGraph GT3©) to capture the daily activity. All participants received a face-to-face introduction with information regarding the aims and course of the study and the use of the smartphones and accelerometers. Furthermore, all participants provided a written consent to participate in the study.

Three questionnaires were sent per day– one in the morning (6:30 am) to be completed after getting up, one in the afternoon (4:30 pm) after finishing work, and one in the evening (9:00 pm) to be completed before going to bed. On weekend days, the morning questionnaire was sent at 8:00 am and no after-work questionnaire was sent. In total, 19 daily questionnaires had to be answered (7 mornings, 5 afternoons, and 7 evenings). The participation rate during the seven days of the study was very high, with 97.7% completed questionnaires, 79 participants (85.8%) providing complete data on all seven days, and only three people (3.2%) missing two or three questionnaires.

Variables

Perceived Stress

To assess daily stress, each evening a *Daily Hassle Scale* (Bolger et al., 1989) consisting of 10 items about different stressors (family demands, personal conflicts, conflicts about the child, transportation and financial conflicts) that occurred during the day was used. Work-related stress (e.g., work conflicts or demands), were not included in the daily hassle scale to account for perceived stress independent of full-time or part-time employment across theseven daydiary study,. Participants rated all 10 items on a 4 point Likert-Scale (0 = no to 3 = that is true). To get an overall score of daily hassles, all values were summed. The scale has moderate reliability (Cronbach's α: 0.68 to 0.89; Characteristics of the study population - Table 1). To differ between more stressful than personal weekly mean and less stressful than personal weekly mean days, the person's mean stress level was calculated.

Physical Activity

All participants were provided with an ActiGraph GT3© accelerometer (John & Freedson, 2012), which captured overall daily body movement. Participants were asked to wear the accelerometer on their right hip during the entire day excluding time swimming, bathing or taking a shower (Cain & Geremia, 2011; Swartz et al., 2000). Participants wore the ActiGraph for an average of 14.9 hours per day (min = 10.09 hours to max= 19.2 hours). Therefore, no datasets had to be excluded (Cain & Geremia, 2011; Ward, Evenson, Vaughn, Rodgers & Troiano, 2005). To capture body movement throughout the whole study period, the start and end of a recording was set to a time in the night (4:00am) before and after the first / last questionnaire (Cain & Geremia, 2011). The ActiGraph was initialized with 60 s epoch length, 3 axis counts and 50 Hz (Cain

& Geremia, 2011). Raw data were downloaded into ActiLife5© Software to calculate energy expenditure (kcal) for each hour of wear time. Only the energy expenditure during leisure time was used for further analysis. To calculate this, energy expenditure during working time was subtracted from total energy expenditure on working days. Energy expenditure during work time was excluded based on the assumption that individual physical activity during work is determined by working conditions and job characteristics (active job or desk work); in contrast, the purpose of this study is to research the effects of perceived stress on leisure time physical activity.

Ethics Statement

The survey was conducted with the informed consent of each subject. The study conformed to the Declaration of Helsinki and the ethics guidelines of the German Psychological Society and has been approved by the ethic committee of the University of Konstanz.

Empirical Model

Data Analysis Plan

To analyze the data, a multilevel regression model with time-varying predictor (daily hassles) and time-varying outcome variable (daily energy expenditure in kcal) was calculated, using the syntax command MIXED in SPSS® (IBM, Chicago, IL) 22.0 for Windows.

To analyze the effects of stress within the multilevel regression models, the daily sum for hassles was separated into a within-person and between-person predictor (Hoffman & Stawski, 2009; Skaff et al., 2009). Within-person stress [$\text{WithinPerson}_{\text{Stress;}}$ Level 1] is the intra-individual variability of stress during the week. It represents stress on one occasion in comparison to the normal stress level of the person and is calculated by centering on the person's mean (i.e., the deviation of stress on each day from the seven day mean for each individual) (Hoffman, 2008; Hoffman & Stawski, 2009; Skaff et al., 2009). In contrast, between-person stress [$\text{BetweenPerson}_{\text{Stress}}$; Level 2] represents the individual's mean across the seven days. It demonstrates the inter-individual variability across the sample and represents the average stress level of one person in comparison to the average stress level of others in the sample. It is calculated by centering on the grand mean (Hoffman, 2008; Hoffman & Stawski, 2009; Skaff et al., 2009).

The differentiation between these effects helps to ascertain whether within-person or between-person differences in perceived stress are related to leisure time energy expenditure. For example, with these analyses it may be understood whether a higher stress level on one day effects energy expenditure on the same day independent from the mean stress level of that person, or whether higher mean stress (mean of all days of the week) is associated with energy expenditure independent from the current perception of stress.

In addition to the multilevel regression model, individual within-person effects (individual regression weights) were calculated to capture the effect of daily stress for each person separately.

Analytical Models

The equations in Model 1 represent the baseline multilevel regression model for energy expenditure during leisure time (Y_{di}) as the function of an individual intercept (β_{0i}) and the residual energy expenditure during leisure time (r_{di}) on a day d for the individual i.

(1)

$$Level\ 1:\quad Y_{di} = \beta_{0i} + r_{di}$$

$$Level\ 2:\quad \beta_{0i} = \Upsilon_{00} + U_{0i}$$

Model 2 presents the multilevel regression model to examine the effect of perceived stress on the daily leisure time energy expenditure.

(2)

$$Level\ 1:\quad Y_{di} = \beta_{0i} + \beta_{1i}(WithinPerson_{Stress}) + r_{di}$$

$$Level\ 2:\quad \beta_{0i} = \Upsilon_{00} + \Upsilon_{01}(PersonMean_{Stress}) + U_{0i}$$

$$\beta_{1i} = \Upsilon_{10} + U_{1i}$$

At Level 1, the energy expenditure (in kcal) during leisure time (Y_{di}) is a function of an individual intercept (β_{0i}), the within-person effects of stress (β_{1i}) and the residual energy expenditure during leisure time (r_{di}) on a given day (d) for an individual (i). On Level 2, the individual intercept (β_{0i}) is a function of the fixed intercept (Υ_{00}), the main effects of within-person daily stress (Υ_{01}), and an individual-specific random intercept (U_{01}). The individual effect of within-person stress (β_{1i}) is a function of the fixed effect (Υ_{10}) and individual-specific random effects of within-person stress (U_{1i}). Maximal likelihood estimation was used to compare the fit of the models (Hoffman, 2008; Hoffman & Rovine, 2007; Hoffman & Stawski, 2009; Skaff et al., 2009).

Results

Table 15 / S3 presents frequencies, means, and standard deviations for all variables. The study sample perceived low levels of stress during the week (M = 3.84; SD = 3.01; range = 0 - 30). On average, men spent 519.00 kcal (SD = 360.04) and women 407.61 kcal (SD = 257.56) during leisure time. Compared to data from the 2003-2004 National Health and Nutrition Survey (NHNS) (Troiano et al., 2008), the sample spent overall slightly more time with light and lifestyle activities (activities between 1.1 and 3 MET (Cain & Geremia, 2011; Freedson, Melanson & Sirard, 1998)) and spent on average more kcal/h than the comparison sample of the NHNS sample (analyzed with the comparison toolbox within ActiLife 5 – data not shown).

Table 15 / **S3:** Characteristics of the study population

	Total (N = 92)		**Men (n = 31)**		**Women (n = 61)**	
	M	**SD**	**M**	**SD**	**M**	**SD**
Frequency			33.60%		66.30%	
Age	45.22	8.0	43.63	1.66	46.24	6.22
Mean Daily Hassles	3.84	3.11	3.62	2.38	3.84	2.25
Daily Energy Expenditure during leisure time	442.13	188.68	519.00	199.97	407.61	171.33

Note: Characteristics of study population; Means (M) and Standard Deviation (SD) of analyzed variables; Age in years. Daily Hassles: sum score of 10 item scale (min = 0; max = 30); Daily energy expenditure in kcal during leisure time measured by ActiGraph.

Energy expenditure during leisure time had an ICC of .699, which requires a multilevel model approach (Hoffman & Stawski, 2009). This high ICC indicates that the between-person variance dominates the within-person variance within the sample, suggesting that individuals widely differ from each other for this variable.

Perceived Stress and leisure time activity

The results of the multilevel regression model (Table 16 / S3) with time-varying predictor and outcome variables showed neither a significant within-person nor a between-person effect of perceived stress on the energy expenditure during leisure time. This means that neither the individually perceived stress on one day in comparison to other days for the same person, nor the mean stress level of a person in comparison to other people, had significant effects on energy expenditure during leisure time on that day. According to this analysis, perceived stress did not affect leisure time PA when compared to more and less stressful days.

Table 16 / **S3**: Random effect multilevel regression model of within-person and between-person effects of stress on energy expenditure (in kcal) during leisure time

		Estimate	SE	p
Intercept		414.64	21.27	.00
Within-Person Stress		5.11	6.41	.42
Between-Person Stress		5.86	9.27	.53
-2LogLikelihood	Empty Model	9068.65		
	Random Effect Model	49816.51		
Chi²		4152.14		.00

Note: Random effect multilevel regression model of within-person and between-person effect of stress on energy expenditure (in kcal) during leisure time. Estimates. Standard Errors (SE). and p-values -2LogLikelihood values – comparison of empty model and random effect model according to Chi² contribution

Individual Perspective

It was assumed that there are inter-individual differences in the reaction to stress; however; the results of the multilevel models indicated no within-person effect of daily perceived stress on individual energy expenditure. Therefore, more detailed and individual analyzes are required to detect the assumed individual differences.

Hence, the individual daily energy expenditure was descriptively related to the individual daily stress level on the same day. The energy expenditure during leisure time on the most stressful day was analyzed in contrast to the energy expenditure during the least stressful day. The results are presented in line charts in Figure 17 / S3. Figure 17 / S3 shows that most participants change their energy expenditure during leisure time on the most stressful day when compared to the least stressful day.

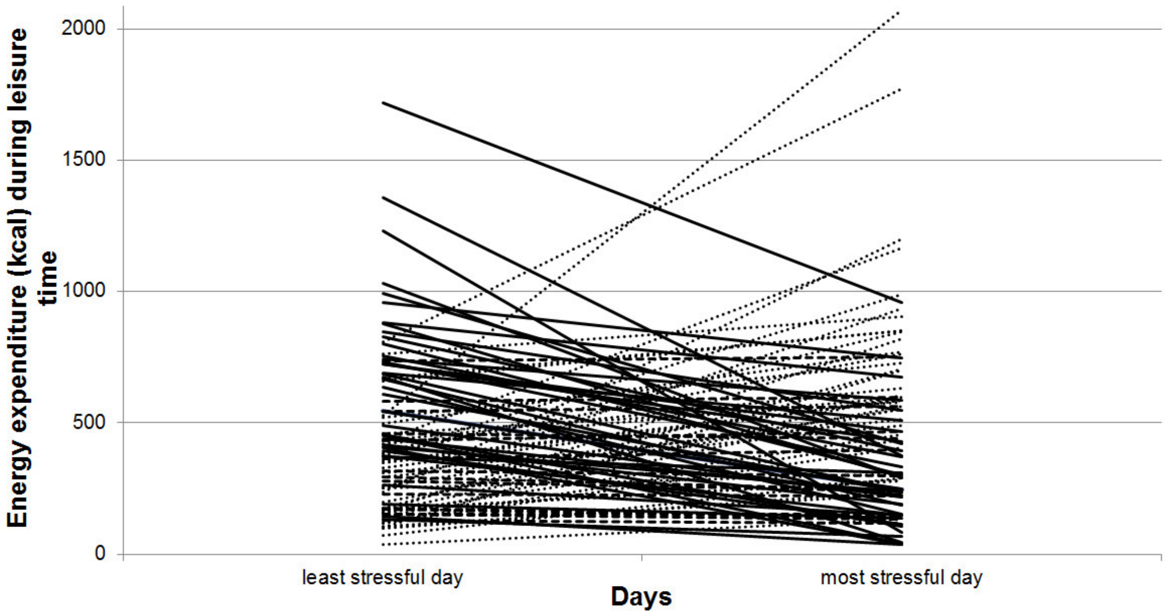

Figure 17 / S3: Individual plots for the energy expenditure during leisure time on the most stressful day vs. the least stressful day for each person in the sample

Line charts revealed three different groups: the *Reducers* (persons with a minimum energy reduction of 100 kcal), the *Increasers* (persons with a minimum energy increase of 100 kcal, which represents the app. energy expenditure of light activities compared to sedentary behavior (Matthews et al., 2008)), and the *Maintainers* (persons who change their energy expenditure within 100 kcal). *Reducer*s lowered their energy expenditure during leisure time between the most stressful day and the least stressful day on average of 340.38 kcal. In contrast, *Increasers* raised their energy expenditure by about 382.62 kcal. *Maintainer*s only minimally changed their energy expenditure (Table 17 / S3). Figures 18/ S3 a-c show the groups separately.

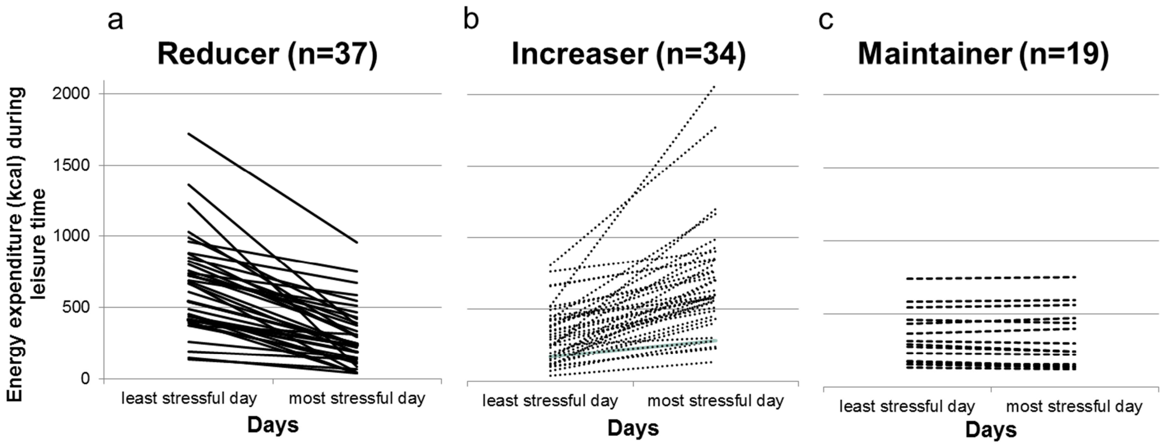

Figure 18 / S3: Group differences in energy expenditure between the most stressful day and the least stressful day - 9a: Reducer (n=37); 9b: Increaser (n=34); and 9c: Maintainer (n=20)

To validate these groups for more "normal" days the mean energy expenditure during leisure time was calculated for all days with less and more perceived stress than the individual person weekly. As before, the results are shown in line charts to demonstrate individual changes (Figure 19 / S3). Figure 19 / S3 shows that most participants, although with a lower mean energy expenditure during leisure time, change their energy expenditure on days with more stress than the personal weekly mean compared with days with less stress than the personal weekly mean. The line charts indicate the same three groups: the *Reducers*, the *Increasers,* and the *Maintainers*. *Reducer*s lower their mean energy expenditure during leisure time on average between days with more than weekly personal mean stress and days with less than personal weekly mean stress by about 157.78 kcal. In contrast, *Increasers* raise their energy expenditure by about 219.23 kcal. *Maintainer*s only minimally change their energy (Table 17 / S3). Except for four participants, all participants remained in the same group they had been in the comparison above.

Figure 19 / S3: Individual plots for the mean energy expenditure during leisure time on less stressful than personal weekly mean days compared to more stressful than personal weekly mean days for each person of the sample

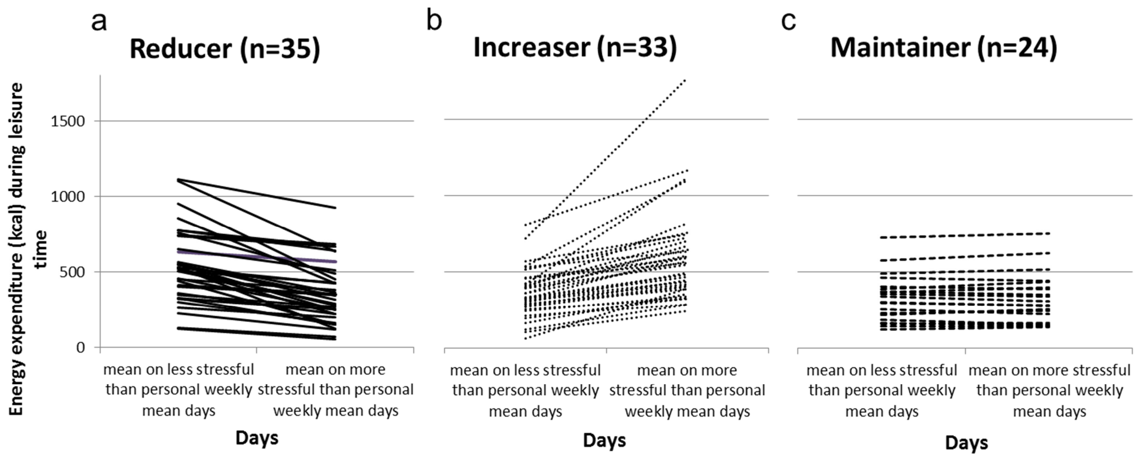

Figure 20 / S3: Group differences of mean energy expenditure between less stressful than personal weekly mean days compared to more stressful than personal weekly mean days - 11a: Reducer (n=35); 11b: Increaser (n=33); and 11c: Maintainer (n=24)

To statistically support the classification of these three different groups, the within-person coefficient was estimated for each participant according to the multilevel regression model presented above. The results indicate and underline the empirically found groups. This means *Reducers* receive negative estimates, *Maintainers* estimates near zero, and *Increasers* positive estimates. Except for two participants, the statistical analyses support the group memberships found in the plot line analyzes above. Table 17 / S3 presents the mean estimates for each group, as well as the mean energy expenditure during leisure time for the most stressful day compared to the least stressful day, and for more stressful than personal weekly mean days compared to less stressful than personal weekly mean days.

Table 17 / S3: Characteristics of Reducers. Maintainers. and Increasers: Mean differences of energy expenditure during leisure time and Estimates of the multilevel regression model

	Most stressful vs. least stressful day		**More stressful vs. less stressful than personal weekly mean days**		**Multilevel regression model**	
	N	**Mean differences kcal**	**N**	**Mean differences kcal**	**N**	**Estimate**
Reducer	37	-340.38	35	-157.78	36	-57.07
Maintainer	19	-27.72	24	-3.02	21	-.90
Increaser	34	382.62	33	219.23	33	59.25
Overall sample without group differences	92	-1.53	92	19.53	92	4.48

Note: Comparison of mean differences of energy expenditure during leisure time of the most stressful day compared to the least stressful day; on less stressful than personal weekly mean days compared to more stressful than personal weekly mean days; negative values indicate a reduction of the energy expenditure, positive values an increase; Multilevel Regression model: Within-person effects of stress on energy expenditure during leisure time. Comparison of the groups – *Reducer*, *Increaser*, and *Maintainer* compared to the overall sample without group differences

Discussion

The purpose of this diary study was to examine the relationship between perceived stress and physical activity by taking into account the day-to-day fluctuation of both variables as well as inter-individual differences in this relationship.

The multilevel regression model did not detect any within-person effect of daily perceived stress on the daily energy expenditure during leisure time. However, the detailed individual analysis of the energy expenditure during leisure time on days with higher or less than average stress revealed a different pattern of responses. Some individuals increased their energy expenditure during leisure time on stressed days, others decreased their energy expenditure, and a third group did not change their energy expenditure. These data correspond with the current literature. A recent review from Stults-Kolehmainen and Sinha (2014) concluded that while most studies report a negative association (higher stress goes along with a reduction in physical activity), some studies have found a positive association (higher stress goes along with more physical activity), and studies discern no association (more stress is not related with physical activity) (Stults-Kolehmainen & Sinha, 2014).

Therefore, the current and previous data suggest an individualized pattern of effects of perceived stress on physical activity. This supports the assumption that people perceive stress differently and as a consequence behave differently when stressed: some reduce and others increase or do not change their energy expenditure during leisure time.

A possible explanation for this could be the fact, that physical activity is sometimes employed as an emotion-focused coping strategy (Wijndaele et al., 2007). In these cases, physical activity provides a detachment from stress, e.g. job demands, family conflicts, or time pressure (Feuerhahn et al., 2012; Sonnentag, 2012). Physical activity and exercise can help a person relax, recharge lost resources, and find new avenues for social support, all of which may assist in the search for solutions for life’s problems (Bauman et al., 2013).

The depletion of personal resources, e.g. self-control, during stressful situations and periods may lead to in the decrease in PA (Baumeister et al., 1998; Muraven & Baumeister, 2000). Individuals who are not habitually physically active and intrinsically motivated to be so, may need more self-control to resist an alternative and possibly more attractive behavior. If the resources are depleted as consequence of stressful situations, this may result in a behavior less exhausting or demanding, e.g. being sedentary and watching TV. It could be assumed that persons who exercise habitually and enjoy exercising maintain or increase their physical activity while persons who are not exercising regularly or who are exercising for external reasons tend to decrease their physical activity. Lutz, Stults-Kolehmainen and Batholomew (2010) demonstrated that only persons on a high regulatory state of behavior increase their physical activity during and after stressful situations and periods. According to Lutz, Stults-Kolehmainen and Batholomew (2010) this changed behavior can be found especially in persons who are planning to be active however not habitually active (at lower states of regulatory behavior).

A third group of people does not change their physical activity level on stressful days. However, the results show that most of these people seem to be relatively inactive regarding their daily energy expenditure. It can be assumed that normally inactive people don't start to be physically active during leisure time when they are stressed.

To sum up, the presented study identified inter-individual differences in the effect of daily perceived stress on individual daily physical activity. The diary study design made a more detailed view possible; taking into account the short term effect of a time-varying variable on another time-varying variable. Additionally, the detailed analysis of individual changes on day-level, exceeding statistical analyzes, illustrates individual differences of stress-induced behavior changes.

To the best of our knowledge, very few studies have analyzed individual effects of daily perceived stress on daily physical activity and none have used a comparable study design. Stults-Kolehmainen and Sinha (2014) only found one study, which indicates different groups of individual effects of stress on physical activity. Seigel, Broman and Hetta (2002) reported that 22.0% of their random sample of 726 Swedish women responded with increased physical activity during stressful periods; 60.1% responded that stress does not change their activity level, and 16.5% reported that stress may inhibited activity level. The authors compared the three groups according to their actual and habitual physical activity levels, and found that females reporting stress-induced activation reported significantly higher amounts of habitual physical exercises and activity than the other groups (Seigel et al., 2002). Seigel, Broman and Hetta. (2002) analyzed the effect with a cross-sectional study design and divided the three groups a-priori. The authors suggest, that the found results should be verified with diary studies or within experimental settings to research the effects of different stressors and to gather information about the cause and effect relationship. Nevertheless, this result supports the link between stress-induced behavior change and the state of habituated physical activity (Lutz et al., 2010).

Limitations and further research

The current study design and results have various limiting factors, which may be starting points for further research.

Study Participants: Most of the participants of this study had a high level of education, which may have led to a greater understanding of health related issues and, therefore, to better health behavior (Droomers, Schrijvers & Mackenbach, 2001; Droomers, Schrijvers, Van De Mheen & Mackenbach, 1998). In future studies a more diverse sample should be included. *Measurement of physical activity:* Accelerometry measures the body movement, e.g. in this case on the hip. It is well known and discussed, that certain activities like cycling or rowing cannot be measured in detail using this device (John & Freedson, 2012; Leenders, Nelson & Sherman, 2003; Warren et al., 2010). However, the ActiGraph was used due to its wide usage and its relative ease of use for participants (Hansen, Kolle, Dyrstad, Holme & Anderssen, 2012). *Measurement of stress*: The Daily Hassle Scale is a widely used tool to measure perceived stress. The current sample seemed to perceive low levels of stress using this scale; however, no true reference values of the daily hassle scale in a diary setting could be found prior to this study. Future studies may improve the measurement of daily stress (Stults-Kolehmainen & Sinha, 2014)with the inclusion of different sources of stress (e.g. work stress or work demands).

Confounding variables: The current study does not attempt to explain individual differences by confounding variables, such as gender, race, individual coping styles, personal resources (e.g., self-control or self-efficacy). Further studies should include potential moderating and mediating variables (Seigel et al., 2002; Stults-Kolehmainen & Sinha, 2014).

Study design: A diary study design improves understanding of dynamic processes by permitting a day level analysis of time-varying variables. However, the cause and effect relationship can only be clarified with the use of experimental methods to manipulate stress, a difficult task for the field researcher.

Conclusion

The results indicate inter-individual differences in physical activity depending on the level of perceived stress. 42.2% of the participants reduce their energy expenditure during leisure time on stressful days, in contrast 36.9% of the participants increase their energy expenditure during leisure time, and additionally 20.7% of the participants do not change their activity level. According to these results, individual differences overall and individual differences in personal factors due to stress-induced behavioral changes should receive greater attention in future research.

Chapter 4: Summary and General Discussion

During the last couple of years, the perception of stress has become a common phenomenon across the globe (World Health Organization, 2008, 2010a). Unfortunately the perception of stress is directly linked to the development and progression of health problems and diseases (Gerrig & Zimbardo, 2008b). Undoubtedly, regular physical activity and an overall active lifestyle are highly beneficial for individual health and the prevention of health problems and diseases (Dishman et al., 2004). In the context of stress, this raises the question of what role physical activity may play in the stress–health relationship. The purpose of this dissertation is to gain more detailed insights into the physical activity – stress – health relationship.

According to the transactional model of stress (Lazarus & Folkman, 1986) and the Social Cognitive Theory (Bandura, 1986, 1989b), stress occurs in the reciprocal interaction of the individual with their direct environment. Within these reciprocal interactions the individual appraises the given situations according to his or her personal resources. Stress occurs when the given internal or external demands exceed the amount of personal resources and with that the ability to handle the situation and cope with the results. Everybody perceives stress as a normal element of daily life and normally able to master stressful situations without any stress induced health problems. However, if stress appears prolonged or chronic, it results in a loss of resources and a chronic inflammation of the organism. This, in turn, has negative effects on individual health.

Concerning physical activity in this context and its relationship with individually perceived stress and individual health, Fuchs, Hahn, and Schwarzer (1994) developed a systematic framework with different roles of physical activity and its relationships to stress, personal resources, and individual health. Physical activity is discussed as having various direct and moderating effects on the three element of the framework, as well as on the interactions between the elements. This framework represents the basic theoretical outline of this dissertation. Using this outline, the different roles of physical activity in the stress-resources-health relationship are discussed. This framework also provides the starting points for the presented studies and a systematic literature review.

Physical activity has direct positive effects on individual physical, physiological and mental health. Epidemiologic research demonstrates that especially regular, long-term physical activity seems to be most beneficial.
The first publication presented in this dissertation reviewed the effects of long-term physical activity on major risk factors, such as weight-gain and obesity, and the development of three common noncommunicable diseases, namely coronary heart disease, type 2 diabetes mellitus, and Alzheimer's disease as well as dementia. For all researched health problems and diseases, long-term physical activity seems to be beneficial (Berenzen et al., 2007; Chang et al., 2010; Demakakos et al., 2010; Di Pietro et al., 2004; Dishman et al., 2004; Donahue et al., 1988; Gillum et al., 1996; Gordon-Larsen et al., 2009; Hankinson et al., 2010; Larson et al., 2006; Laurin et al., 2001; Lee & Paffenbarger, 1998; Mozzafarian et al., 2009; Must et al., 1992; Petersen et al., 2004; Rodriguez et al., 1994; Sesso et al., 2000; Vogel et al., 2009). However, the reviewed studies demand a certain minimum of intensity, duration, and regularity of physical activity for best results (Clarke & Janssen, 2013; Demakakos et al., 2010; Di Pietro et al., 2004; LaMonte & Blair, 2012; Petersen et al., 2004).

Concerning the relationship between physical activity and individually perceived stress, physical activity and perceived stress are directly and indirectly related. The analysis of the direct relationship between physical activity and individually perceived stress raises the question of the direction of effects between physical activity and individually perceived stress: Does physical activity have effects on the perception of and reactivity to stress? Or in contrast, does individually perceived stress lead to a change in individual physical activity?
Concerning indirect effects between physical activity and individually perceived stress, physical activity is discussed as a moderator variable, buffering negative effects of stress on individual health. This means, if a person perceives high amounts of stress, physical activity is able to lower the negative effects of individually perceived stress on individual health.

Study 1 researched this buffering effect of physical activity and activities of daily living on various stress-induced health complaints.

This study advances and connects previous research results. It expands the existing studies by to two major points concerning the buffering effect of physical activity: It compares physical activity and activities of daily living and analyzes different health outcomes.

In a first step, the study distinguishes between various health complaints as outcome variables. This differentiation between physical and mental health complaints merges previous study results in one study, and provides the opportunity for comparing the buffering effect with the type of outcome variable. The leading question is, whether there are differences in the buffering effect with regard to physical and mental health complaints, and whether physical activity is able to buffer the negative effects of perceived stress better in relation to physical or mental health complaints (Gerber & Pühse, 2009).

The results indicate that physical activity has slightly stronger buffering effects for physical than mental health complaints. However, the results also show that physical activity was not able to buffer the negative effect of stress on every researched health complaint. In addition to these inconsistent buffering results, the results indicate that other variables, especially age and gender, seem to be important covariates, which may be the reason for these inconsistent findings.

For this reason, in a second step, the buffering effect of physical activity was compared with the buffering effect of activities of daily living. It was assumed, the spent energy alone, not the way how this energy expenditure was achieved, was responsible for health improvements or buffering effects (Carmack et al., 1999).

However, the results indicate that the energy expenditure of activities of daily living are neither related to individual health complaints, nor act as a buffering variable in the stress-health relationship. Since even high amounts of daily activities did not improve the general health or act as a buffering variable in the stress-health relationship. In this study, physical activity alone had this buffering effect.

Different reasons may explain this inconsistent effect of physical activity and activities of daily living.

One important reason is mental detachment during physical activity sessions (Sonnentag, 2012). During physical activity, the person has the opportunity to detach from individual stressors, recharge lost resources, and thereby gets a chance to improve and protect their own health against stress-induced problems and diseases. In contrast, a normal active lifestyle with different activities of daily living, such as cycling to the shop or walking the dog, provides no or only a few opportunities for mental detachment.

However, this raises the question why physical activity seems to be a better buffering factor for physical than mental health complaints. It is imaginable, that this difference is caused by a study bias and the superimposition of information, e.g. due to other variables such as coping strategies, personal characteristics, or other unknown effecting variables. Further studies should integrate effect variables such as individual characteristics.

The study results show further aspects concerning the physical activity-stress-health context.

First of all, the results indicate, that physical activity and perceived stress are closely related to each other. This represents the direct relationship between physical activity and perceived stress in the theoretic outline of Fuchs, Hahn, and Schwarzer (1994). According to this theoretic framework, and as discussed above, both directions between physical activity and stress are plausible and explainable.

In contrast to Fuchs, Hahn, and Schwarzer (1994) and Fuchs (2003), who concentrated on the effect of physical activity on stress reactivity, the results of study 1 suggest the other direction of this relationship - the effect of stress on physical activity. Individually perceived stress and physical activity are negatively significantly related. However, further regression analyses showed that the effect of perceived stress on the energy expenditure due to physical activity is significant and stronger compared to the effect of the energy expenditure due to physical activity on perceived stress. Using this result and following Fuchs, Hahn, and Schwarzer (1994) and Fuchs (2003), who discuss both directions as plausible and explainable, this dissertation concentrates on this direction of the relationship between physical activity and individually perceived stress.

Secondly, the study results indicate, that further variables, such as personal and environmental characteristics, e.g. age and gender, are important in the physical activity-stress-health context. Furthermore, since individuals are mostly embedded in a social context, elements of this social context might be important as well and should be included in further studies.

As a third leverage point for further studies, it is suggested to take into consideration that both individually perceived stress and physical activity are fluctuating variables, and that there could be a relationship between these two variables on a daily level, but not for weeks or months. Additionally it should be considered that the perception of stress and physical activity can fluctuate throughout the day. To overcome this problem, a more time-specific research design is necessary. The use of diary or ambulant assessment techniques is recommended.

Concerning the second effect of individually perceived stress on individual physical activity, in a first step, it is necessary to supply a theoretical background for describing this direction of the relationship before presenting study results (Study 2 and Study 3).

Bandura's (1989) Social Cognitive Theory is a useful framework for determining and describing individual behavior in the reciprocal interaction with personal characteristics and the environment the person lives in. The key element, the triadic reciprocal determinism, elucidates the relationships and connections the three elements, the person themselves, their behavior, and their environment.

Within this model, stress occurs as a result of the individual appraisal of the interaction between internal or external personal resources and internal or external demands (Person, Behavior, and Environment). Individual stress becomes part of the triadic reciprocal determinism and occurs in the reciprocal interactions, affecting the elements and interactions.

An enormous amount of literature supports the assumption that individually perceived stress affects the person themselves and their behavior as well as the interaction between these elements of the model (Adkins & Premeaux, 2012; Balantekin & Roemmich, 2012; Bauer et al., 2012; Bevan & Reilly, 2011; Everly Jr. & Lating, 2013b; Garasky, Stewart, Gundersen, Lohman &

Eisenmann, 2009; Lundahl et al., 2013; Mouchacca et al., 2013; Payne et al., 2012; Randall & Bodenmann, 2009; Seaward, 2011; Westman, 2011).
However, most studies limit their research to one person, i.e. the effect of stress on the person themselves, their characteristics, and their behavior. Only few studies extend their research to the effects of stress in personal relationships, mostly on couples / dyads (Anderson, Hughes & Fuemmeler, 2009; Randall & Bodenmann, 2009; Westman, 2011; Westman & Etzion, 2005). However, considering the fact that the family is an important social context in which a person grows up and learns basic health behaviors, the extension of the Social Cognitive Theory framework to the family may enhance current literature findings on the effects of stress (Baranowski, 1997; Baranowski et al., 1996; Taylor et al., 1994). Within the daily life of families', children learn healthy behavior and the necessity of sufficient physical activity in daily life in order to obtain and maintain a healthy lifestyle (Bauer et al., 2012; LaGuardia & Patrick, 2014). Thus, the family plays a crucial role in learning healthy behavior and preventing the development of risk factors and diseases. However, stress is also a common element of families, affecting individual behavior and thereby the family environment (Bevan & Reilly, 2011).

Study 2 focused on on the inter- and intra-individual effects of individually perceived stress on different health behaviors in a family approach which included parents and children.

The first part of this study researched intra-individual effects of different sources of stress on different parameters in relation to physical activity, time spent with sedentary behavior, and nutrition[9] for each family member.
The differentiation of different sources of stress and different family members improves current literature. The results indicate the different sources of stress have different effects overall, and the effects differ in direction and strength

[9] Each participant rated their individual frequency of consumption of certain foods in a Food Frequency Questionnaire. Ten items of the Food Frequency Questionnaire were selected and the given ratings were summed up to a *core food index* (muesli, salad, fruits, vegetables, dairy products, fish) and a *non-core food index* (non-core foods: chocolate, sweets, cakes, salty snacks), respectively. The selection was made on the basis of the guidelines of the Australian National Health and Medical Research Council (1995). According to these guidelines core foods comprise types of foods that are part of a healthy nutrition, in contrast, non-core foods reflect an unhealthy nutrition (Bell et al., 2005; Johnson et al., 2011; National Health and Medical Research Council, 1995)

between the family members. For example, higher perceived stress due to work overload of mothers goes along with a less frequent consumption of core food and a more frequent consumption of non-core food. In contrast, mothers consume core food more frequently and non-core food less frequently when stressed due to social tension. For children perceived stress is not significantly related to nutrition. These differences indicate that the effects of perceived stress on individual health behavior are individual. People react individually to the perception of stress and behave in different ways depending on the reasons for stress. In order not to miss these individual effects, further studies should analyze the individual effects on a personal level, not on an overall level.

The second part of the study researched inter-individual effects of stress on the individual health behavior of the family members. It was investigated whether the perceived stress of one family member, e.g. the mother, has effects on the health behavior of other family members, e.g. the child.

Similar to the inter-individual analyses, the intra-individual analyses indicate that the different sources of stress differ with regards to their effects on different health behaviors and different family members. Three main aspects of these effects could be identified.

(1) *The important role of the mother:* Perceived stress of the mother affected the health behavior (especially physical activity and the consumption of core and non-core foods) of the other family members, in particular that of the child. The mother seems to act as a gate keeper for health related behavior within the family (Bauer et al., 2012; Bevan & Reilly, 2011). Thus it is recommended to support and provide opportunities for stressed mothers to maintain their health related behavior even when stressed. A more effective division of domestic work and a better compatibility of family and career could be beneficial for maintaining healthy behavior and for supporting mothers in being a good role model for children (Bevan & Reilly, 2011).

(2) *The parent-dyad:* The results of the study indicate that the perceived stress of one parent affects the other parent's behavior. This happens especially regarding leisure time sedentary behavior. Here the relationships between the division of domestic work and the compatibility of family and career seem to be two important factors. Work stress is often related to long working hours away from home. More time spent away from home inhibits an adequate division of

housework among both parents and in consequence one partner has to perform the family related tasks which the other partner is not able to do (Baxter, 2000). This leads to a lack of time (e.g. no time for leisure time sedentary behavior) resulting in higher perceived stress for the partner (Westman, 2001, 2011; Westman & Etzion, 2005).
(3) *The effect of the child:* Greater perceived overall stress and stress due to school overload of the child was associated with more sedentary behavior of both parents. To the best of my knowledge, no other study has researched the effect of perceived stress of the child on other family members. All other found studies, that included different family members researched the effects of the family environment or only the effect of the mother on the behavior of the child and not vice versa (Bauer et al., 2012; Bevan & Reilly, 2011; LaGuardia & Patrick, 2014). These results highlight the reciprocal interactions within the family environment. Each family member affects the family environment and thereby other family members, and is in turn affected by the family environment. This is not only the case for adult family members.

The results of the study indicate that individually perceived stress is related to individual health behavior as well as the health behavior of other family members. Furthermore, the results emphasize the importance of distinguishing between different health behaviors (core and non-core food consumption, physical activity, and sedentary behavior) and between different sources of stress (family, work, personal conflicts). Further studies should consider individual differences and effects, and research individual effects on an individual level.
The extension of the family environment, by including other family members, enriches previous results and adds a new perspective to the link between stress and health behavior - the importance of the social context (Bauer et al., 2012; Bevan & Reilly, 2011; LaGuardia & Patrick, 2014). These insights into the inter-individual interactions between the family members, i.e. the individuals and their shared environment, should especially be included in the development of intervention programs for improving and maintaining individual health behavior when stressed.

Despite all these improvements, such as the differentiation between different sources of stress and the individual analyses of different persons, the study only had a cross-sectional design. In contrast, individually perceived stress and physical activity are fluctuating variables and may be closely related on a daily level, but not over weeks or months. In order to capture both and research the effects more closely, diary or ambulant assessment techniques are necessary.

Therefore, study 3 addressed the individual differences and the time fluctuations of the variables stress and physical activity and researched the individual effects of daily perceived stress on daily leisure time activity with a day-to-day diary approach.

This study contributes to the current literature in two ways: Firstly, the day-to-day approach provided detailed information about the time fluctuation of daily stress and daily physical activity. Secondly, physical activity was measured with an accelerometer, worn the whole day, which provided more detailed and objective results about the daily activity level than questionnaires.

The purpose of this study was to examine whether the participants changed their individual activity level on stressful days compared to less or non-stressful days (within-person effect). Additionally it was examined whether all participants changed it in the same way.

The result of a multilevel regression model, analyzing the within- and between-person effects of stress on leisure time activity, indicates no significant effects of individually perceived stress on the individual daily energy expenditure during leisure time. In general, the participants did not change their individual activity level during leisure time when stressed. This result corresponds with previous literature results (Stults-Kolehmainen & Sinha, 2014).

However, a descriptive analysis of the individual daily energy expenditure illustrated the relationships between the individual daily stress and physical activity level. Individual line charts of the energy expenditure during leisure time were created. The line charts displayed the energy expenditure between the most stressful and least stressful day as well as the mean energy expenditure during leisure time on less stressful and more stressful days than the personal weekly mean. The charts indicate that the participants react individually when stressed. A detailed analysis of the individual changes showed three different groups: some participants increased their activity level while others reduced or did not change it. Overall, the individual beta-estimates and the individual change in the energy expenditure during leisure time statistically annulled each other. This could be the reason for the results of the multilevel regression model. These results correspond with the review results of Stults-Kolehmainen and Sinha (2014), who detected positive, negative, or no relationships in their reviewed studies.

The results of this diary study indicate that a detailed analysis of the individual level of the effects of individually perceived stress on the level of physical activity is necessary. However, this raises the question, why some people increase their activity level, while others reduce it or do not change it at all.

Individual detachments from stressful situations, such as job demands, family conflicts, or time pressure (Feuerhahn et al., 2012; Sonnentag, 2012), are a potential explanation for an increase in physical activity after stress. During physical activity, such as exercises, a person can relax and recharge lost resources. In addition to this mental disengagement, social exchange during physical activity may provide social support and offer possible solutions or help for a stressful problem (Bauman et al., 2013).

Additionally, the depletion of personal resources, such as self-control, during stressful situations and periods may lead to a decrease in physical activity (Baumeister et al., 1998; Muraven & Baumeister, 2000). This seems to be the case especially for people who are neither intrinsically motivated anor habitually physically active. They may need more self-control to resist an alternative and possibly more attractive behavior. If the personal resources are depleted as a consequence of a stressful situation, this may lead to a behavior less exhausting or demanding, for example sitting and watching TV.

A third group of people do not change their physical activity level on stressful days. However, the results show that most of these people seem to be relatively inactive regarding their daily energy expenditure. It is safe to assume that usually inactive people do not start to be physically active when stressed.

These explanations lead to a further aspect which seems to be important in the explanation of physical activity changes during and after stressful situations.

The regulatory state of behavior, this means the state of habitualisation of physical activity, seems to affect individual behavior. It can be assumed that persons who exercise habitually and enjoy exercising maintain or increase their physical activity level, while persons who are not exercising regularly or who exercise for external reasons tend to decrease their physical activity. Lutz, Stults-Kolehmainen, and Bartholomew (2010) demonstrated that only persons on a high regulatory state of behavior increase their physical activity during and after stressful situations and periods. In contrast, inactive or irregularly active people do not change their activity level or decrease it during and after stressful periods.

In further studies, the regulatory state of physical activity should be integrated to verify this explanation.

The three studies of this dissertation researched three aspects of physical activity in the relationship between individually perceived stress and individual health. Physical activity is important for individual health as well as for the perception of stress and its effects on individual health. On the other hand, physical activity, as an important health behavior, is in turn affected by the perception of stress. However, the results indicate that the relationship between these three elements, individual stress, physical activity, and individual health, is more complex than assumed. The presented studies indicate that further variables, such as age, gender or personal characteristics, affect the interactions between stress, physical activity, and health.

Due to the novelty of the used methods, especially in study 2 and study 3, this dissertation was able to reveal and highlight complex effects of individually perceived stress on the individual as well as on inter-individual health behavior. Especially study 3 with its individual diary method was able to capture the time-varying variables; individual stress and individual physical activity. This analysis revealed the individuality in the relationship of stress and physical activity – people react individually to the perception of stress.

Despite with all improvements and the contribution to the field of research, the three presented studies have limitations and highlight different points for further research.

Limitations, further research and conclusion

(1) Inclusion of further variables

It is obvious that people react individually to the perception of stress. Therefore it is assumed that personal characteristics, such as self-esteem or the habitual state of a certain behavior are very important for maintaining this behavior during and after stressful periods (Lutz et al., 2010). The presented results indicate that other variables such as personal characteristics, e.g. self-esteem, self-efficacy, or personal attitudes, as well as age and gender, seem to have confounding effects on physical activity and individual stress. Further studies should include personal resources and characteristics to research the potential effects and to analyze which personal characteristics are the most important for the relationship between physical activity and individual stress. Additionally, environmental characteristics, such as the Family Health Climate (Niermann et al., 2014), should be integrated in further analyses.

Closely connected to these results, the presented studies did not differ in individual coping strategies. It is plausible that individual emotion focused coping strategies have an effect on stress-induced behavior changes. For example, an increase in physical activity seems to be realistic, when the person uses active coping strategies, such as visiting physical activity lessons, going jogging or cycling. In contrast, a reduction of the physical activity level is plausible, when the person uses more inactive coping strategies like watching TV. The inclusion of individual coping strategies seems to be beneficial for explaining the found effects (Stults-Kolehmainen & Sinha, 2014).

(2) Study participants

All presented studies include voluntary participants following the Declaration of Helsinki. However, especially in the context of communal health studies (Study 1), voluntary participants are generally more interested in the topic of the study. Different other studies show that interested participants have a healthier lifestyle than other people. All presented studies seem to have a study bias due to the fact that the participants already had a healthy behavior (Jungbauer-Gans, 2006; Jungbauer-Gans & Gross, 2006). Moreover, in study 2 and 3 people with higher education were over-represented which may have led to a higher understanding in health related issues and to a better health behavior of the participants (Droomers et al., 2001; Droomers et al., 1998). In further studies, other social groups should be included.

(3) Measurements of physical activity and stress

The presented studies indicate a major problem of this field of research. Most studies differ in their definition and operationalization of stress and physical activity. Even the presented studies do not use the same scale of stress and physical activity. It is difficult or even impossible to compare results across different studies (Stults-Kolehmainen & Sinha, 2014). In a next step, it is necessary to review study results in relation to the used operationalization of stress and physical activity, and to research if the different scales reveal different results (for example, do hassle scales reach different results than subjective valuations of stress?). Further research should integrate these differences of different operationalization of stress and physical activity.

For the operationalization of physical activity, it seems to be beneficial to revert to objective methods of measurement, such as the use of accelerometers. The combination of subjective and objective methods of measurement of physical activity provides the possibility to differentiate between objective effects, such as an improvement in physiological parameters, and subjective effects, such as mental detachment from stress even when no physiological reactions could be achieved (Dishman et al., 2004).

(4) Study designs and analyzes

Since the appraisal of stress and physical activity are very individual variables, the detailed analyses of studies 2 and 3 provided new insights. It could be demonstrated that individual research, going further than the standard statistical analyses (done in study 3), improves the state of the art and was able to detect results which would otherwise have remained hidden. Further studies should integrate a day-to-day approach to directly and individually capture time-varying variables such as individual stress and physical activity. The inclusion of further and more detailed information, as far as it can be measured via an ambulatory assessment approach, seems to be a further improvement to the presented study results.

(5) Theoretical background

This dissertation followed the theoretical framework and outlines of the model of Fuchs, Hahn, and Schwarzer (1994) and the Social Cognitive Theory of Bandura (1989). However, both models are only of a descriptive character and therefore cannot explain why physical activity has exactly these assumed effects. They cannot explain why the results are the way they are.
Further research is necessary to build a testable theoretical background which can describe and explain the relationship and effects between individually perceived stress, physical activity, and individual health.

(6) Intervention programs

The study results indicate that the social context, especially the family, plays an important role in the change or maintenance of healthy behavior during and after stressful situations and periods. For that reason, the social context should be integrated into intervention programs for maintaining healthful behavior when stressed (LaGuardia & Patrick, 2014). On the other hand, the results showed that people behave individually when stressed. Intervention programs, concerning strategies for stress reduction, should provide different and individually tailored strategies for reducing individual stress.

All in all, the analyses indicate, that the relationship between individually perceived stress, individual health, and physical activity is more complex than assumed. Physical activity seems to play an important role in the stress-health relationship. However more and detailed research is necessary. The results showed that physical activity, in contrast to activities of daily living, is able to buffer negative effects of individually perceived stress on individual health complaints. Furthermore, it is obvious that individually perceived stress and physical activity are closely related.

On the one hand, physical activity seems to be a beneficial factor for reducing stress reactivity. On the other hand, individually perceived stress, as well as perceived stress of other family members, has effects on individual physical activity and other health behavior. However, the results indicate that different sources of stress seem to have different effects on health behavior.

Additionally, study 2 and study 3 demonstrated that participants react individually to the perception of stress.

While this dissertation improves the state of the art, more research is necessary to clarify the individual relationship between perceived stress and physical activitv.

“At the end of the day… Keep calm and be active”

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Statement of Authorship

I hereby certify that this dissertation has been composed by me and is based on my own work, unless stated otherwise. This work has not been submitted for any other degree. All published or submitted parts of this dissertation have been proved and agreed by all co-authors and Prof. Dr. Alexander Woll and are cited in the part “Publications of this Dissertation”.

Karlsruhe. September 2014 Miriam Reiner