Stress-Buffering Effects of Physical Activity and Cardiorespiratory Fitness in Police Officers - A Real-Life Study

Inaugural dissertation
to be awarded the degree of Dr. sc. med.

presented at
the Faculty of Medicine
of the University of Basel

by
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from
Leipzig, Germany

Basel, 2020

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Basel, August 13th, 2020

"*Our job is keeping 99 percent of the population safe from the other one percent,…The problem is we have to spend half our lives with that one percent, and the better we do our job, the less the other 99 think they need us. They are clueless. The only ones paying attention on the streets are the cops and the criminals. Everyone else is just going somewhere or shopping.*"

Washington Post, 2018, p. 24

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Acknowledgements

This dissertation is the result of circuitous efforts and contributions. I would like to express my personal gratitude to every involved person and institution. I sincerely thank all participants from the police corps Basel-Stadt for their attendance in the study. I particularly thank Simon Spoerri and Daniela Montinari for their permission for and support of this research endeavour. I am also grateful to Martin Roth, commandant of the police corps, for addressing all employees in a personal video message. Thanks to Dagmar Irlenbusch for her contribution to the internal communication. Special thanks to the entire team of the education and training center of the police force for their support in establishing a laboratory and executing the study based on their internal information system. Particularly helpful to me were Jeannine Hess, Roland Jäger, Patrick Meier, Dieter Pfäffli, Michaela Rutschmann, Andi Sonntag, and Urs Stehrenberger. Stefan Klossner was especially helpful in creating the study video.

I would like to acknowledge the assistance and effort of all students involved in the project. Eveline Schärli helped in the validation study of the SIMPAQ questionnaire, provided great support in establishing the study material, video footage, and handling questionnaire data. Many thanks to the Master students Mario Metzger, Sarah Müller, Benjamin Grossmann, and Nico Güdel who established and executed the lifestyle-coaching and laboratory assessments. Thanks also to Lara Allemann, Cenk Cigerli, Saskia Frei, Laura Fuchs, and Felix Wendland for their efforts.

I would like to extend my sincere thanks to Andrea Meyer from the Institute of Psychology of the University of Basel, who has been paramount in his contribution to my statistical training and who patiently provided statistical advice. I also wish to thank all colleagues who greatly participated in the preparation and finalization of the present publications. Many thanks to, Simon Rosenbaum, Attilio Carraro, Lars Donath, Oliver Faude, Xenia Fischer, Philip B. Ward, and Lukas Zahner. I very much appreciate the instructive and trustful support of Serge Brand.

I must also thank the entire team of the Departement of Sport, Exercise and Health for providing a unique, supportive, and enjoyable work environment. I especially thank Patricia Arnaiz, Johanna Beckmann, Jan Degen, Stefanie Gall, Tim Hartmann, Nandi Joubert, Simon Kohler, Anothony Laissue, Christin Lang, Vera Nina Loser, Sebastian Ludyga, Ivan Müller, Cornelia Pagoni, Varenka Strobel, Marina Wälti, and Anita Weiss. Special thanks to Harry Seelig, who never wavered in his supportive professional and statistical advice.

It has been a privilege to enjoy the company and friendship of my closest colleagues, who created an environment beyond the limits of an excellent workplace. Therefore, my personal thanks to Robyn Cody, Flora Colledge, and Manuel Mücke for their professional, creative, advisory and joyful support, which was especially helpful in the final phase of this PhD. I would also like to express my gratitude to Christian Hermann, who extended a great amount of assistance in the statistical models that were crucial to this project. I would like to express my deepest appreciation to my committee. Many thanks to Uwe Pühse for opening doors, and constantly supporting me during my PhD. I cannot begin to express my thanks to my first supervisor Markus Gerber, for his advice, experience and insight into his scientific work. His constant support, constructive criticism, and patience cannot be underestimated. From the early project application, over feverish efforts in establishing an agreement with the police force, to the publication process, the success of this PhD would not have been possible without his contributions.

I am more than grateful for the love and support of my family. I thank my parents and my brother, for their steady encouragement and patience that helped me on my entire academic journey. I sincerely thank my godchild for cheering me up with a vividness that sharpened my eyes for the important things. I thank my flatmates for making the place of living a home, and for providing their support and patience, especially in the final phase in a very unusual situation. I would like to express my deepest appreciation to my closest friends Hendrik, Jana, Linus, Matthias and Patrick, who always inspired and motivated me.

List of abbreviations

AA	Ambulatory assessment
ANS	Autonomic nervous system
CRF	Cardiorespiratory fitness
CVD	Cardiovascular disease
CSA	Cross-stressor adaptation
EMA	Ecological momentary assessment
ERI	Effort-reward imbalance
GDP	Gross domestic product
HPA	Hypothalamus-pituitary-adrenal
HR	Heart rate
HRV	Heart rate variability
JDC	Job demand and control
MetS	Metabolic syndrome
PA	Physical activity
RMSSD	Root mean square of successive differences
SAM	Sympathetic adrenal medullary
SD	Standard deviation
SIMPAQ	Simple Physical Activity Questionnaire
SMBM	Shirom-Melamed Burnout Measure
TSST	Trier Social Stress Test

Summary

Background: In modern society, psychosocial stress is a major health threat, related to cardiovascular disease and impaired mental well-being. The workplace constitutes a main source of stress in western countries. The related physiological and mental health impairments are manifold and well-documented, and the associated costs for individuals and society are considerable. Promising evidence suggests physical activity (PA) and cardiorespiratory fitness (CRF) may be public health resources that buffer the negative effects of stress on health. However, evidence from laboratory studies is conflicting to some extent, and research to elaborate previous findings in externally valid conditions is required. To date, research has primarily been based on retrospective self-reports, and studies in realistic circumstances are scarce. This project was designed to examine the stress-buffering effects of PA and CRF on physiological and psychological health in realistic circumstances with a comprehensive methodology. A central goal of the current study was to investigate underlying mechanisms in line with the cross-stressor adaptation hypothesis (CSA) on psychophysiological stress responses. Dynamic psychophysiological processes were captured using newest methodological developments of Ecological Momentary Assessment (EMA) and Ambulatory Assessment (AA), as well as sophisticated statistical models.

Research objectives: In a one-year prospective study with a sample of 201 police officers, exposure to chronic and acute work stress was examined, along with cardiometabolic and mental health parameters. PA was assessed over seven consecutive days via accelerometry, substantiated by a recently developed and validated questionnaire (Simple Physical Activity Questionnaire; SIMPAQ). CRF was objectively measured with the submaximal Åstrand cycling test. Chronic work stress was observed based on the job-demand and control (JDC) model, as well as the effort-reward imbalance (ERI) model. Acute work stress was measured using smartphone-based EMA of current stress experiences, whereas physiological responses were captured using AA of heart rate variability (HRV). Cardiovascular risk factors (waist circumference, blood pressure, blood sugar, blood lipids) were assessed in a laboratory setting and psychological health outcomes (Burnout, sleep health, psychological distress) via online-questionnaire. The first hypothesis posited moderating effects of PA and CRF on the association between chronic work stress, cardiometabolic health, and mental health. Higher levels of PA and CRF were suggested to be related to improved cardiometabolic and mental health, with stronger effects when levels of chronic work stress were higher. Hypothesis testing was performed using cross-sectional and prospective regression analyses. The second research question focussed on the CSA hypothesis. Lower physiological stress reactivity and increased physiological stress recovery were expected for individuals with higher levels of PA (results not shown), as well as CRF. Physiological stress reactivity was defined as changes in HRV which were matched to the individuals' specific stress experiences. Physiological recovery was investigated by measuring HRV during the following night. Hypothesis testing was performed using multilevel models and regression analysis.

Results: The validation studies supported the suitability of the applied questionnaires for the assessment of PA and burnout. The main finding was that no stress-buffering effects of PA appeared in the data. Furthermore, CRF partially occurred as a stress-buffer on the cross-sectional association between ERI scores and cardiovascular risk factors, whereas no stress-buffering effects occurred on metabolic syndrome and mental health. The second major finding was that PA did not appear to influence physiological stress reactivity or recovery. However, CRF partially buffered physiological stress reactivity, whereas no effect occurred on physiological stress recovery. CRF was related to a more favorable stress reactivity regarding feelings of stress, whereas no effects occurred for feelings of anger, positive or negative affect. Aside from these main findings, PA was significantly and negatively correlated with metabolic syndrome scores after one year. CRF was a reliable significant predictor for lowered cardiovascular risk factors, including metabolic syndrome after one year. Additionally, CRF showed significant associations with more favorable day and night HRV levels. The present findings must be cautiously interpreted because of non-probability sampling. Furthermore, an inconsistent relationship between work stress and physiological outcomes might have lowered the detectable effects. This could be due to the high activity and fitness levels in the present sample, which may have entailed a ceiling effect.

Conclusion: This is one of the first real-life studies examining the stress-buffering effects of PA and CRF in realistic circumstances and with such comprehensive methodology. In summary, CRF appeared as an important health resource with the potential to buffer some of the associations between stress and health risk factors. Therefore, the consistent and routine measurement of CRF should be addressed in occupational health programs for police officers, and constant efforts to encourage individuals to improve and preserve CRF levels should be made. PA has to be measured more precisely to elaborate acute and regular differences and interactions with fitness, and differences in leisure time and work-related PA, especially in a physically demanding work environment. Research with longer follow-up periods including continuous/multiple measurements is warranted to elaborate important health related effects and mechanisms more precisely.

Zusammenfassung

Hintergrund: Psychosozialer Stress ist in unserer heutigen Gesellschaft eine ernstzunehmende Bedrohung der Gesundheit, da dieser mit kardiovaskulären Erkrankungen und verringertem mentalen Wohlbefinden assoziiert ist. In westlichen Ländern ist der Arbeitsplatz erheblich mit der Erscheinung von Stress verbunden. Die vielfältigen physiologischen und mentalen Gesundheitsbeeinträchtigungen, die mit beruflichem Stress einhergehen, sind gut dokumentiert. Die damit verbundenen Kosten für die Betroffenen und die Gesellschaft sind immens. Empirische Befunde zeigen, dass körperliche Aktivität und kardiorespiratorische Fitness das Potential haben, als Gesundheitsressourcen die negativen Auswirkungen von Stress zu puffern. Laborbefunde weisen jedoch gewisse Widersprüche auf, weshalb Studien höherer externer Validität gefordert sind. Bisherige Studien zu diesem Thema sind deutlich unterrepräsentiert und basieren zumeist auf retrospektiven Selbstberichten. Das hiesige Projekt wurde erstellt, um die stresspuffernden Effekte körperlicher Aktivität und Fitness auf physiologische und psychologische Gesundheit in einem realistischen Umfeld anhand einer umfangreichen Methodologie zu untersuchen. Hierbei war ein Hauptziel der Untersuchung, zugrundeliegende Mechanismen der Stressantwort in Hinblick auf die Cross-Stressor Adaptationshypothese zu ergründen. Um die dynamisch ablaufenden psychophysiologischen Prozesse festzuhalten, wurden die Methoden Ecological Momentary Assessment (EMA) und Ambulatory Assessment (AA) auf Basis neuester Technologien kombiniert. Die so gewonnenen Daten wurden mit angemessen anspruchsvollen statistischen Modellen ausgewertet.

Methoden: In einer einjährigen prospektiven Studie wurden 201 Polizisten auf ihr chronisches und akutes Stressempfinden hin untersucht. Gleichzeitig wurde ihre kardiometabolische und mentale Gesundheit erfasst. Körperliche Aktivität wurde über sieben Tage objektiv mit Akzelerometern gemessen und durch einen neu entwickelten und validierten Fragebogen (Simple Physical Activity Questionnaire, SIMPAQ) ergänzt. Kardiorespiratorische Fitness wurde mit dem submaximalen Åstrand Fitnesstest mit einem Radergometer erfasst. Die Erhebung des chronischen Berufsstresses orientierte sich am Anforderungs-Kontroll-Modell und am Modell beruflicher Gratifikationskrisen. Akuter Berufsstress wurde mittels Smartphones psychologisch erfasst (EMA) und auf die physiologische Stressantwort auf Basis der Herzratenvariabilität (AA) abgeglichen. Kardiovaskuläre Risikofaktoren (Bauchumfang, Blutdruck, Blutfett, Blutzucker) wurden im Labor erhoben, wohingegen psychologische Gesundheitsparameter mit einem Onlinefragebogen (Burnout, Schlafgesundheit, psychologischer Distress) gemessen wurden. Die erste Hypothese vermutete moderierende Effekte körperlicher Aktivität und kardiorespiratorischer Fitness auf die Beziehung

zwischen chronischem Berufsstress und kardiometabolischer, sowie mentaler Gesundheit. Hierbei wurde vermutet, dass höhere Werte von körperlicher Aktivität und kardiorespiratorischer Fitness mit besseren Gesundheitswerten bei hohem erlebten Stress einhergehen. Diese Hypothese wurde mit querschnittlichen und prospektiven Regressionsanalysen untersucht. Übereinstimmend mit der Cross-Stressor Adaptationshypothese wurde mit der zweiten Hypothese vermutet, dass körperliche Aktivität und kardiorespiratorische Fitness mit einer verringerten physiologischen Stressantwort einhergehen. Hierbei wurde die physiologische Stressreaktion als die Veränderung der Herzratenvariabilität in individuell spezifisch wahrgenommenen Stressmomenten definiert. Die physiologische Erholungsfähigkeit wurde über die Herzratenvariabilität der folgenden Nacht erfasst. Diese Hypothese wurde mit Mehrebenenmodellen und Regressionsanalysen untersucht.

Ergebnisse: Die Validierungsstudien bestätigten die Anwendbarkeit der Fragebögen zur Erfassung von körperlicher Aktivität und Burnout. Die Hauptbefunde der Untersuchung zeigten keine stresspuffernden Effekte körperlicher Aktivität. Kardiorespiratorische Fitness zeigte hingegen teilweise stresspuffernde Effekte auf die querschnittliche Verbindung zwischen Berufsstress, gemessen anhand des Modells beruflicher Gratifikationskrisen, und kardiovaskulären Risikofaktoren. Es zeigte sich jedoch keine stresspuffernde Wirkung auf das metabolische Syndrom und mentale Gesundheit. Der zweite Hauptbefund offenbarte keine Einflüsse von körperlicher Aktivität auf die physiologische Stressantwort. Kardiorespiratorische Fitness erwies sich hingegen teilweise als Stresspuffer auf die physiologische Stressreaktivität, jedoch nicht auf die physiologische Stresserholung. Die Effekte auf die physiologische Stressreaktivität zeigten sich in einer verringerten Reaktivität in Verbindung mit Stressgefühlen, wohingegen keine Effekte für Gefühle der Wut, sowie positiven und negativen Affekt auftauchten. Neben diesen Hauptbefunden war körperliche Aktivität signifikant mit geringeren Werten des metabolischen Syndroms nach einem Jahr verbunden. kardiorespiratorische Fitness zeigte sich sehr zuverlässig und signifikant mit geringeren Werte kardiovaskulärer Risikofaktoren, einschliesslich Werten des metabolischen Syndroms nach einem Jahr. Ausserdem war kardiorespiratorische Fitness mit bevorzugten (höheren) Werten der Herzratenvariabilität am Tag und während der Nacht verbunden. Diese Befunde müssen vorsichtig interpretiert werden, da es sich nicht um eine Zufallsstichprobe handelt. Ebenfalls zeigte sich keine zuverlässige Verbindung zwischen Berufsstress und den physiologischen Parametern. Dies könnte mit den verhältnismässig hohen Aktivitäts- und Fitnesswerten in der Stichprobe zusammenhängen, welche weiterhin einen möglichen Deckeneffekt nicht ausschliessen lassen.

Schlussfolgerungen: Die hier vorliegende Arbeit ist eine der ersten prospektiven Studien im realen Umfeld, die mittels einer derart umfangreichen Methodologie durchgeführt wurde. Insgesamt zeigte sich kardiorespiratorische Fitness als ein bedeutender Gesundheitsfaktor mit dem Potential, einige

Folgen von Stress auf die Gesundheit zu puffern. Daher sollte kardiorespiratorische Fitness im beruflichen Gesundheitsmanagement für Polizisten berücksichtigt werden. Neben routinierten und konsistenten Messungen kardiorespiratorischer Fitness, sollte gleichermassen die Ermutigung der Angestellten zur Verbesserung und Aufrechterhaltung der kardiorespiratorischen Fitness im Fokus stehen. Körperliche Aktivität sollte genauer betrachtet werden, um die Unterschiede zwischen akuten und Langzeiteffekten und deren Interaktion mit Fitness untersucht werden. Besonders in körperlich anspruchsvollen Berufen sind die unterschiedlichen Effekte zwischen freizeitlicher und beruflicher Aktivität von Interesse. Um mögliche Gesundheitseffekte körperlicher Aktivität und kardiorespiratorischer Fitness und zugrundeliegende Mechanismen genauer zu untersuchen, empfehlen sich längere Beobachtungszeiträume und kontinuierliche/multiple Messungen.

1. Introduction

1.1 Stress and health

Psychosocial stress is a major health threat in industrialized countries (Gerber & Schilling, 2018; Tomitaka et al., 2019). Mental and physical illness can occur when optimal functioning of an individual’s stress system is distorted. However, stress is not regarded as negative per se. Hans Selye, a pioneer in stress research, noted that stress reactions all share commonalities, leading him to describe the general adaptation syndrome of stress reactivity (Selye, 1950). This syndrome consists of three phases; alarm, resistance, and exhaustion. In his first animal studies, Selye showed that the alarm phase and the resistance phase mobilized the biological system to succesfully overcome external demands. The animals would recover completely so long as they were not stressed to the point of exhaustion. In this phase, the system collapses, ultimately leading to disease or death. These insights provided helpful explanations for the pathways between stress and disease (Goldstein & Kopin, 2007). However, in early research, the term stress did not differentiate between the cause and the effect. Furthermore, Selye felt that stress is the “salt of life” (Selye, 1956). This means that Selye understood stress as an essential part of life. On this understanding, constant stress-induced adaptations are necessary to survive. The absence of these demands and adaptations would be similar to death. Based on these more educated insights, Selye later referred to the cause of stress as a “stressor”, and he divided stress into the positive “eustress” and negative “distress”. In the present study, the term stress is used synonymously with distress, as is the case in common parlance (Goldstein & Kopin, 2007).

Another important development in early stress research is based on the work of Walter Cannon. Cannon understood the stress related physiological phenomena as a dynamic equilibrium counterbalancing external demands. In this respect, Cannon coined the term homeostasis, which refers to the ongoing stabilization and defense of vital physiological variables, such as blood pressure (Cannon, 1929). These stabilising responses appeared to be goal-driven, which explains Cannon’s phrase “wisdom of the body” (Cannon, 1932). These concepts provided by Selyse and Cannon shaped earliest stress research in the midth 19th century. In line with these reaction-oriented concepts, research focused on specific stressors and responses. Major life events, chronic strains and daily hassles, have been identified as psychosocial stressors showing important associations to health (Kasten & Fuchs, 2018). Health-relevant physiological response patterns have been described for biological, psychological and behavioral phenomena (Kasten & Fuchs, 2018). However, the idea of homeostasis did not sufficiently explain observable systemic adaptations to long-term stressors, including variance in reactions to equal stressors or anticipatory reactions. In order to explain these adaptations and the link between stress and illness more accurately, several concepts have been proposed (Goldstein & Kopin, 2007). To date, allostasis is the most widely accepted of these concepts (Ramsay & Woods, 2014; Sterling & Eyer, 1988). Sterling and Eyer (1988) defined allostasis as achieving stability by change. More specifically, the defended baseline level changes in order to adequately cope with externally or internally presented demands (Ramsay & Woods, 2014). Furthermore, optimal coping would be centrally commanded by regulatory processes in the brain (Ramsay & Woods, 2014). More modern models developed into an understanding of a transactional process between the individual and the environment (Lazarus, 1984). Transactional stress models more adequately accounted for the complexity and individuality of the stress process (Gerber, 2020; Lazarus, 1984). In the presentation of transactional models, stress depends on how an individual's cognitive, endocrine, and nervous system perceives, processes and interprets external demands (primary appraisal), and the resources (secondary appraisal) available to manage them (McEwen & Gianaros, 2010). This process can undergo (multiple) re-interpretations (reappraisal). While psychological stress has been shown to be consistently linked to discrete emotions, Lazarus and Cohen-Charash (2001) further supported the assumption that psychological stress and emotions are not seperable.

The translation of these theoretical assumptions into measurable physiological manifestations draws on two main stress axes, predominantly assigned to the autonomic nervous system (ANS) and the neuroendocrine system. In acute stress situations, the sympathetic adrenal medullary (SAM) system activates the ANS (Pruessner & Ali, 2015). In order to initialize the so-called "fight or flight" response, sympathetic activity is increased immediately, whereas parasympathetic activity is reduced (Pruessner & Ali, 2015). This leads to typical stress responses, such as an increased heart rate (HR) and decreased heart rate variability (HRV) (Uusitalo et al., 2011). Mediated by adrenaline and noradrenaline (for example), blood pressure and platelet aggregation in the periphery increases (Pruessner & Ali, 2015; Veldhuijzen van Zanten et al., 2004). Moreover, the brain is activated and the organism is provided with additional energy (Pruessner & Ali, 2015). The hypothalamus-pituitary-adrenal (HPA) axis is a neuroendocrine stress system (Allen, Kennedy, Cryan, Dinan, & Clarke, 2014). Although slower in its process sequence than the ANS, this axis is more reactive to psychosocial stressors. Even the anticipation of a threat can enhance HPA activity (Pruessner & Ali, 2015). Scholars believe that close interactions exist between these two stress systems, the immune system, and cognitive processes (perception of a stressor) (Pruessner & Ali, 2015; Uchino, Smith, Holt-Lunstad, Campo, & Reblin, 2007).

Activities of the stress axes influence several effector systems. They range from executive cognitive functions to the reward and fear system, sleep-wake cycle mechanisms, growth, reproductive and thyroid hormone axes, and the gastrointestinal, cardiorespiratory, metabolic, and immune systems (Chrousos, 2009). Consequently, a malfunctioning stress system can contribute to a multitude of health impairments. Chronically elevated level of stress have shown to be a salient risk factor for metabolic syndrome (MetS) (Gerber & Schilling, 2018; Kaltsas & Chrousos, 2007). MetS is a cluster of risk factors, and considered a global burden due a close relation to cardiovascular disease (CVD) (Gaziano, 2012; Saklayen, 2018). According to the World Health Organization (WHO, 2018), CVD are the leading cause of deaths worldwide. Psychosocial stress has shown to be a risk factor for CVD with an impact comparable to smoking or diabetes (Russ et al., 2012). Furthermore, evidence implies a dose-response relationship between psychosocial stress and CVD-related premature death (Kaltsas & Chrousos, 2007; Russ et al., 2012). While ANS activity has been shown to mediate stress-induced hypertension and heart disease (Hering, Lachowska, & Schlaich, 2015), psychosocial stress has been suggested to influence multiple cardiovascular mechanisms related to cardiac events (Bairey Merz et al., 2002).

1.2 Occupational stress

The occupational environment constitutes a major source of stress in western countries (American Psychological Association, 2017). Despite efforts to decrease work stress, no substantial changes in prevalence have been achieved in Europe (Eurofound, 2017). In 2018, a Suisse-wide survey including 2946 participants, has shown that 27.1% of employees reported to be overly stressed (Gesundheitsförderung Schweiz, 2018). These developments appear to be concerning, due to evidence indicating severe health consequences related to work stress. Literature reviews of cross-sectional and prospective studies have shown a strong association between work stress and CVD, with a doubled risk for future CVD in highly stressed individuals (Nyberg et al., 2013; Siegrist & Dragano, 2008). Research on work stress has also highlighted the association between stress and mental well-being (Quick & Henderson, 2016). This is noteworthy, as the social burden of mental disorders in high-income countries is tremendous, with costs estimated at 2.3 to 4.4% of the national gross domestic product (GDP) (Marquez & Saxena, 2016). Depression is is the leading mental health impairment (Steinmann, 2005). Based on their review of prospective epidemiologic studies, Siegrist and Dragano (2008) concluded that high occupational stress is associated with a 1.2 to 4.6-fold increased risk for depression. Additionally, occupational stress has been described as the main cause of burnout among adult workers (Maslach, Schaufeli, & Leiter, 2001), and seems to be closely associated with sleep complaints (Akerstedt et al., 2002). Accordingly, costs associated with occupational stress (i.e., due to health care, absenteeism, presenteeism, reduced productivity, increased turnover) remain high, and have been estimated at 0.5 to 1.2% of the GDP (Guazzi et al., 2014). This is in line with a recent report in Switzerland, estimating these costs to be 1% of the GDP (Gesundheitsförderung Schweiz, 2018). Given the negative individual and societal consequences associated with occupational stress and psychosocial stress in general, finding ways to improve resiliency against stress is a major public health concern (Kivimäki et al., 2002; Semmer & Zapf, 2018).

In line with the above-mentioned theoretical foundations, work stress research applies transactional stress models (Landsbergis et al., 2017). These models mainly account for cognitive evaluations of job related demands and resources in terms of a fit between the individual and the environment (Hart & Cooper, 2001). Within this framework, stress occurs if the perceived demands of the work environment, and resources of the individual, do not balance (Landsbergis et al., 2017). This fit or congruence has been characterized in the context of two components. The first is a demand-ability fit, which refers to the external demand that work imposes on the individual, and the individual ability to meet this demand. The second is a fit between the individual's demands or needs and the provided or available resources (Dewe, O'Driscoll, & Cooper, 2012). In this respect, modern, sophisticated models of occupational stress integrate complex environmental interactions. The job demands and control (JDC) model, for example, evaluates perceived demands, such as time pressure and work overload. These demands are related to the perceived control, which is the decision latitude at work (Karasek, 1979). The control component accounts for a lack of stimuli, information, and competencies. The effort-reward imbalance model, on the other hand, postulates that stress emerges due to a perceived mismatch in the calculation of job related costs and benefits (Siegrist, 1996). The effort component can emerge from external (tasks by a supervisor) as well as internal (overcommitment) sources. Reward, on the other hand, can be perceived as emotional and financial appreciation, but also job safety and gratification. JDC and ERI are two of the most widely accepted work stress models, and therefore, the focus of the current study. Different work stress models have been proposed in the literature, and the rapidly developing employment relationships of the 21st century encourage conceptual disscussions about adapted theoretical models (Kelliher, Richardson, & Boiarintseva, 2019; Mark & Smith, 2008). However, to stay in the scope of this work, these will not be addressed here (see Dewe et al. (2012) and Mark and Smith (2008) for more information).

Based on the concepts described above, the implementation of work stress management programs can focus on multiple factors. These factors can be narrowed down to two categories, work conditions and employee behaviour (verhaltens- und verhältnisbezogene Massnahmen) (Ulich, 2012). Work conditions may include the reduction of stressors, such as time pressure or workload, but also the creation of appealing work requirements, such as balanced variability and complexity. Behavioural strategies, on the other side, can aim to improve individual's resources, which may include stress management seminars and health behaviour coaching (Ulich, 2012; Vincent, 2012).

In Switzerland, work related prevention of disease and health promotion are regulated on a federal level. Since the beginning of this century, the foundation "Gesundheitsförderung Schweiz" organizes projects that address stress management interventions in Switzerland. The SWiNG study, for example, provided evidence for the success of an intervention in eight companies with more than 5000 employees (Gesundheitsförderung Schweiz, 2011). The study showed positive influences on individual and organizational levels that improved employees' perceived imbalance between resources and demands in 25% of all participants. While these results show the potential of appropriate occupational health management strategies, current federal law is mainly limited to occupational safety and accident prevention. Based on these limitations, Gesundheitsförderung Schweiz (2020) provided quality standards, called "Friendly Work Space", in 2009. However, a proposed federal law to improve the current legal framework was rejected in 2012, and the implementation of the mentioned quality criteria remains optional for companies (Gesundheitsförderung Schweiz, 2020). Until today, approximately 80 organizations, employing approximately 200.000 individuals in total, use the label Friendly Work Space in Switzerland.

While these measures are promising, the situation for many employees in Switzerland remains adverse. In a nationwide study by Grutsch and Kressig (2015), employees rated occupational health management as the most relevant work- and society-related issue. The second and third most relevant factors were wage settings and technological resources. Furthermore, the results showed a discrepancy between the perceptions of demands for occupational health promotion between employers and employees. This discrepancy is particularly stark for supported psychological health in coping with occupational strain (Grutsch & Kressig, 2015). While these results show the relevance of occupational health promotion, in Switzerland, the prevalence of overly stressed employees has increased over the last six years (Gesundheitsförderung Schweiz, 2018). These developments are concerning, and appropriate solutions to tackle the negative consequences of stress in the workplace are demanded.

1.3 Stress buffering effects of physical activity and fitness

The health benefits of both physical activity (PA) and fitness are well-known (Myers et al., 2015; Pate et al., 1995). PA is bodily movement "exerted by skeletal muscles that results in energy expenditure above resting level" (Caspersen, 1985, p.126). Fitness is the sum of attributes or characteristics an individual has or achieves, enabling to perform PA. These attributes can be health and skill related (Ferguson, 2014). This work generally considers health related fitness. Although fitness can be influenced by PA, particularly exercise, it is genetically determined and influenced by environmental factors (Martinez-Vizcaino & Sánchez-López, 2008). Although they are interrelated, insufficient levels of PA and fitness have been shown to be independent health risk factors (Ekelund et al., 2007; Myers, Kokkinos, & Nyelin, 2019; Myers et al., 2015). Furthermore, fitness is suggested to predict health risk outcomes more accurately (Brown, 1991; Myers et al., 2015).

Since the early 80s, scholars suggest stress-buffering effects of PA and fitness. While PA and resulting fitness have been shown to protect against the health impairments that are related to psychosocial stress (Van der Doef & Maes, 1999), the mechanisms are less clear. The cross-stressor adaptation (CSA) hypothesis suggests that PA elicits a stress reaction in the human body, and that the organism's reactions to it are beneficial for different stressors (Sothmann et al., 1996). These adaptations can result in more adequate physiological regulations in psychosocial stress situations (Gerber, 2012; Sothmann et al., 1996). Furthermore, PA and fitness are both thought to improve psychological well-being and thus promote the ability to cope with psychological stressors (Gerber, Börjesson, Ljung, Lindwall, & Jonsdottir, 2016; Gerber, Lindwall, Lindegard, Borjesson, & Jonsdottir, 2013c; Gerber & Pühse, 2009).

Previous research on CSA focused on the effects of cardiorespiratory fitness (CRF) on stress reactivity and recovery (Crews & Landers, 1987). However, three meta-analysis examining laboratory studies showed heterogeneous results (Crews & Landers, 1987; Forcier et al., 2006; Jackson & Dishman, 2006). In 1987, Crews and Landers revealed that CRF was negatively associated with stress reactivity. Almost 20 years later, Forcier et al. (2006) applied more strict inclusion criteria and found similar results, namely decreased stress reactivity and slightly increased stress recovery in more fit individuals. However, in the same year Jackson and Dishman (2006) published their work, showing that higher CF levels were not related to decreased stress reactivity, although stress recovery increased considerably. While Forcier et al. (2006) focused on ANS stress reactivity, Jackson and Dishman (2006) additionally included proxies of the HPA axis. Furthermore, the stressors applied in the included studies differed considerably, limiting the comparability of the mentioned results. With induced stressors ranging from cognitive and behavioral to physical challenges, some scholars have argued that related results are not comparable to studies applying psychosocial stressors (Hamer, 2012; Kasten & Fuchs, 2018). Understanding psychosocial stress as a more specific concept, recent research has often applied the Trier Social Stress Test (TSST) (Kirschbaum, Pirke, & Hellhammer, 1993). Due to a combined application of psychosocial and cognitive stress, researchers consider the TSST more reliable (Allen et al., 2014). The TSST has been shown to increase HPA and ANS axis activity, alter cardiovascular and immune system activity, and to heighten self-reported stress, anxiety, and negative mood (Allen et al., 2014; Dickerson & Kemeny, 2004). Nonetheless, only relatively few studies have tested the CSA hypothesis of PA and CRF with the TSST (Mücke, Ludyga, Colledge, & Gerber, 2018). Evidence supporting reduced stress reactivity and recovery has been provided by Rimmele et al. (2007; 2009), Childs and de Wit (2014), and Klaperski et al. (2013; 2014). Klaperski et al. (2014), for example, tested a twelve-week exercise intervention on stress reactivity and recovery in a randomized controlled trial. Participants improved their CRF and showed significantly reduced stress reactivity across all parameters (HR, HRV, and salivary cortisol). Little to no support for the CSA hypothesis was found by Puterman et al. (2011), Strahler et al. (2016), Jayasinghe et al. (2016), and Mücke et al. (2020).

The comparison of these results is difficult for methodological reasons. Both concepts, physical fitness and PA, are closely related, but have shown to be independent health factors (Myers et al., 2015). However, most studies on the CSA hypothesis focused on PA or fitness separately, or employed exercise to increase fitness. Additionally, biopsychological reactions have not been measured consistently; i.e. considering both stress axes (Puterman et al., 2010). Furthermore, the degree to which these results can be translated from the laboratory to real-life remains unclear. Scholars argue that, although psychosocial stress is induced in laboratory studies (TSST), participants might not perceive the stressor tasks as personally relevant (Wilhelm, Pfaltz, & Grossman, 2006; Zanstra & Johnston, 2011). This is aggregated by the fact that these stressors are short-term and can be solved with specific coping skills, whereas stress in real-life is more chronic and complex, and thus requires a more complete repertoire of coping skills (von Haaren et al., 2016; Wilhelm et al., 2006; Zanstra & Johnston, 2011). Therefore, some authors have claimed that in future research, the impact of stress on stress reactivity and well-being should be empirically tested in naturalistic circumstances under more ecologically valid conditions (Lucini, Norbiato, Clerici, & Pagani, 2002).

1.4 Challenges in real-life studies

As mentioned above, the work environment represents a substantial source of stress in industrialized countries (American Psychological Association, 2017). Furthermore, an interaction between PA and CRF with work stress, which may lower the negative consequences for mental and cardiovascular health, has been posited. In a 30-year follow-up study, Holtermann et al. (2010) found that, in participants (men) with low fitness levels, higher physical work demands were related to higher risk of ischemic heart disease and all-cause mortality. This relationship did not occur for participants with high fitness levels, if compared to participants with low physical work demands, which corroborates the expected stress-buffering effects of fitness. While existing studies generally supported stress-buffering effects of PA and fitness on health, to date, occupational stress has not been sufficiently examined (Gerber et al., 2016; Schmidt, Beck, Rivkin, & Diestel, 2016). Previous studies on the topic have mainly used retrospective self-reports as proxies for all variables of interest (Lundgren-Nilsson, Jonsdottir, Pallant, & Ahlborg, 2012; Parikh, Mochari, & Mosca, 2009; Shirom & Melamed, 2006). However, retrospective self-reports entail some considerable limitations in the research on psychophysiological phenomena. In general, recall bias and social desirability might distort the results of subjective reports (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2009; Prince et al., 2008).

More specifically, aggregated mean values of dynamically changing phenomena, such as stress, may show different associations than multiple acute assessments (Lischetzke, 2014). Redelmeier and Kahneman (1996) presented striking results on this topic when they examined pain experiences in colonoscopy patients. Surprisingly, retrospective reports were heavily influenced by peaks and endings of pain experiences, whereas durations disregarded (Zajchowski, Schwab, & Dustin, 2016). Consequently, Kahnemann (2011) introduced the concept of two selves, the "experiencing self" and the "remembering self"; whereas the former represents momentary cognitive, affective, and behavioral responses, the latter interprets experiences, which depends on accuracy of retrieval and reasonable integration (Kahnemann, 2005; Ward & Garety, 2019). Therefore, in order to more directly examine stress responses, a key area of research is the real-time assessment of the experiencing self. Another aspect supporting the demand for multiple momentary assessments relates to the theoretical framework that posits individual differences in the stress process. Intra-individual differences in dynamic processes of interpreting and re-evaluating experiences requires study designs beyond inter-individual levels (Dunton, Whalen, Jamner, & Floro, 2007; Zawadzki, Smyth, Sliwinski, Ruiz, & Gerin, 2017). In this respect, aggregated levels might lead to misinterpretations due to different variations of variables on different levels (Shiffman 2008). These misinterpretations may arise from low or even negative correlations of both levels. A vivid example of the differences that can occur between intra-individual and inter-individual correlations is the association of PA and blood pressure. While values of regular PA are related to reduced blood pressure on an inter-individual level, higher levels of PA are associated with higher blood pressure (i.e. climbing stairs) on an intra-individual level (Kamarck, Schwartz, Janicki, Shiffman, & Raynor, 2003).

Further considerations support the need for multiple assessments in real-time. Dunton (2017) summarised these considerations with the terms synchronicity, sequentiality, and instability. Parameters that co-occur in time and within individuals (synchronicity), that are presumed to be temporal antecedents and consequences/postcedents (sequentiality), and that fluctuate over time and within individuals (instability), cannot be sufficiently accounted for by global retrospective measures. Taken together, different methodologies are needed to build upon current assumptions, and particularly to determine possible mechanisms underlying stress-buffering effects in terms of the CSA hypothesis (Dunton, 2017).

Ecological momentary assessment (EMA) is the methodological response to these limitations and requirements (Shiffman, Stone, & Hufford, 2008). The definition of EMA employed here is the simultaneous assessment of multiple psychological parameters in close-to-real time and in the subject's natural environment (Stone & Shiffman, 1994). These characteristics are highly sought after by researchers, in order to capture emotional-affective representations of stress as they occur, rather than necessitating long recall times (Kahnemann, 2005; Kasten & Fuchs, 2018). The definition for EMA used here refers to paper-pencil methods, as well as technological solutions (Shiffman et al., 2008). Paper-pencil methods have been in use for decades (Dunton, 2017). Newer approaches linked these methods to technology with diary prompts, where a random alarm invited the participants to write about their current emotions or thoughts (deVries, 1992; Hektner, Schmidt, & Csikszentmihalyi, 2007). The most recent developments in handheld computers and smartphones have opened up entirely new opportunities. As such portable electronic devices become more common, they become less costly, and participants are comfortable with using them (Dunton, 2017; Kasten & Fuchs, 2018). Furthermore, these technologies have the capacity to enable quick data collection from large samples, while the data processing is simplified using remote servers and software that prepares data for analyses (Dunton, 2017). Additionally, statistical analyses of the resulting data have developed rapidly. Today, general consensus has been reached about the appropriateness of multilevel models to account for the necessities related to intra-individual data (Beal & Weiss, 2003). In summary, EMA provides a methodological tool for studying momentary processes in realistic settings. This technique offers an adequate logical, operational and analytical approach to minimize shortcomings of traditional self-reports, i.e. recall bias (Beal & Weiss, 2003).

The invariability in previous research may be attributable to methodological developments, or limited realization of the need for momentary assessments in order to support theoretical models. Another explanation may be the technological challenges assessing psychophysiological stress measures in real life (Shiffman et al., 2008). However, technological developments have also lead to significant improvements in capturing physiological data. New technologies in Ambulatory Assessment (AA) have yielded devices that can be worn on a small chest strap, which measure a multitude of physiological parameters, including heart rate, movement, temperature, light, air pressure, and even geo-location (Ebner-Priemer, Kubiak, & Pawlik, 2009; Trull & Ebner-Priemer, 2013). While AA is used as an umbrella term (Fahrenberg, Myrtek, Pawlik, & Perrez, 2007), it will be used to refer to the continuous assessment of physiological parameters in the present work. In stress research, the AA method has shown its potential to adequately capture SAM axis activity in real-world observations (Kasten & Fuchs, 2018; Kudielka, Gierens, Hellhammer, Wüst, & Schlotz, 2012).

Herewith, HRV has become a popular and frequently used parameter, depicting the SAM axis activity more precisely while containing more information than blood pressure and HR alone (Kasten & Fuchs, 2018; Shaffer & Ginsberg, 2017). Furthermore, HR and HRV have been shown to be independently related to stress (Pieper, Brosschot, van der Leeden, & Thayer, 2007). HRV is defined by fluctuations of time intervals between successive heartbeats (N-N intervals), measured in milliseconds. These differences can be attributed to parasympathetic branches of the SAM axis having an influence on sympathetic activity as well (Shaffer & Ginsberg, 2017). Different parameters can be calculated from interbeat intervals, which are attributed to time and frequency domains. This work will mainly focus on time domain parameter root mean square of successive differences (RMSSD), as one of the most frequently examined HRV parameters. RMSSD is relatively free from respiratory influences (i.e. compared to high frequency power), which is an important advantage in situations where respiration frequency might not be accessible, as is this case in real-life measurements (Laborde, Mosley, & Thayer, 2017). While HRV has been related to mental and physiological health (Taylor, 2010), evidence links stress-related differences in HRV with CVD (Hillebrand et al., 2013) and mortality risk (La Rovere, Bigger, Marcus, Mortara, & Schwartz, 1998).

Studies that combined AA with EMA are relatively rare, but have shown that HRV (RMSSD) is related to stress responses in teachers and hospital workers (Pieper et al., 2007; Uusitalo et al., 2011). In a unique real-life study, von Haaren et al. (2016) have combined AA and EMA to examine the CSA hypothesis. In a randomized controlled trial with sedentary university students, aerobic exercise training (20 weeks) increased CRF in the intervention group, which then showed a significantly improved stress response (measured as HRV) during their examination period. A review by Tonello et al. (2014) has shown the current state of research on the general topic of stress-buffering effects of PA and fitness in relation to work stress and HRV. While the authors reported a generally negative interconnection between work stress and HRV, no conclusion could be drawn in regard to PA and fitness. The reason for that was a lack of studies assessing the respective outcomes or reporting possible interactions (Tonello et al., 2014). Taken together, HRV is a feasible and reliable measure of SAM axis activity related to stress. EMA and AA are promising methodologies for research questions highly demanded to build upon current knowledge. Promising results from real-life studies support the CSA hypothesis. However, studies examining personally relevant stressors in realistic contexts with appropriate methodologies are largely underrepresented (Gerber & Fuchs, 2018).

1.5 Real-life stress in police officers

As mentioned above, a major source of stress in everyday life is the workplace. In order to investigate work stress, police officers represent a uniquely interesting population, as they are exposed to several acute and chronic stressors (Brown & Campbell, 1990; McCreary & Thompson, 2006). These stressors include dealing with death, disaster, violence, and sexual crime (McCreary & Thompson, 2006). Police officers have to deal with primary victims of crime as well as offenders. Additionally, potentially armed suspects represent unpredictable life threats that further demand critical decision-making under high pressure (Deschamps, Paganon-Badinier, Marchand, & Merle, 2003; Duran, Woodhams, & Bishopp, 2019; Tadje, 2014). Given these operational stressors, police officers' perceived demand for organizational support can be high, and reports of organizational stressors are frequent. Reported organizational stressors include a lack of support by supervisors, shortage of manpower and equipment, and interactions with the public (Burke & Mikkelsen, 2006). Additionally, police work is organized in strict hierarchical structures. Within these structures, police officers encounter little autonomy, since they have to follow department rules. These rules regulate almost all activities that have to be carried out and reported within the range of standardized operational processes (Brown & Campbell, 1990). Consequently, police officers often report other, less risk-related stressors, such as disproportionate amount of paperwork, repetitive tasks, and courtroom appearances (Violanti et al., 2017). Furthermore, unpredictable long working hours and changing shift work cycles have been shown to be relevant stress factors in police officers (Deschamps et al., 2003). Shift work is generally known to be related to several negative health outcomes, including professional spillover (Landsbergis et al., 2017). Professional spillover, which refers to the effect of work life on different personal domains, is particularly meaningful in police officers. Police officers practice and employ thoughts and behaviors that are necessary for their job, such as emotional distancing, which can be problematic in their private lives (Johnson et al., 2005). Professional spillover can further lead to work and family conflict, which has often been reported in police officers (Hall, Dollard, Tuckey, Winefield, & Thompson, 2010). Additionally, recent societal changes influence police officers' work, and the consequences of these changes for stress experiences have not yet been studied. Cybercrime, human trafficking and terrorism are some examples of new challenges police officers have to face (Campion & Rousseaux, 2015).

As emphasized by Waters and Ussery (2007), while police officers start their career in excellent health, some may develop severe health problems due to the cumulative impact of stress experienced in the line of duty. Reports on stress-related health issues include sleep complaints (Garbarino, Guglielmi, Puntoni, Bragazzi, & Magnavita, 2019), decreased quality of life, burnout, smoking, alcohol consumption (McCarty, Aldirawi, Dewald, & Palacios, 2019; Richmond, Kehoe, Hailstone, Wodak, & Uebel-Yan, 1999; Violanti et al., 2017), and cardiovascular risk (Capitanelli, Garbarino, & Magnavita, 2017). While resulting impairments in performance, increased sick leave and early retirement are associated with organizational and societal costs (Collins & Gibbs, 2003), adequate job performance is also, in this particular profession, essential for public safety (Waters & Ussery, 2007).

Given these circumstances, the current study specifically focused on police officers of the canton Basel-Stadt. While research generally supports the aforementioned stress experiences in Swiss police officers (Arial, Gonik, Wild, & Danuser, 2010; Gerber, Hartmann, Brand, Holsboer-Trachsler, & Pühse, 2010a; Simons & Barone, 1994; Violanti et al., 2017), some peculiarities must be mentioned. The shift work schedule for employees of the police corps Basel City is a regular six-day cycle (see APPENDIX 1). This cycle is generally the same for all employees, although it may differ slightly in certain exceptional circumstances. Although stable shift work cycles are regarded as beneficial for health, the shift work status of police officers in Basel-Stadt has shown to be related to perceived stress and sleep complaints (Gerber et al., 2010a; Gerber et al., 2013b). Furthermore, Basel is one of the larger cities in Switzerland, directly adjacent to Germany and France. Therefore, European open borders and related international traffic influence police work, a particular difference compared to other cantons. In this respect, illegal immigration, international crime and terrorism are well-recognized challenges (Eidgenössisches Justiz- und Polizeidepartement, 2020; Schweizerische Eidgenossenschaft, 2019). However, the police force of Basel-Stadt does not have a conceptual approach to systematically manage occupational health. While stress management seminars are part of educational elements, no regular programs and evaluations are carried out.

In summary, police officers experience a multitude of stressors, with evidence supporting increased work related stress in international and Swiss samples (Arial et al., 2010; Gerber et al., 2010a; Habersaat, Geiger, Abdellaoui, & Wolf, 2015; Violanti et al., 2017). Furthermore, police officers have been shown to be at risk for maladaptive coping strategies (Aaron, 2000). For example, seeking professional assistance for stress management may be seen as a weakness (Richmond et al., 1999). Therefore, research in police officers is highly warranted, yet still underrepresented (Violanti et al., 2017).

1.6 Summary and study outline

In past research, much evidence has accumulated demonstrating the negative impact of occupational stress on workers' health. Developing promising health resources to counteract the negative consequences of psychosocial stress is of the utmost importance. In this respect, previous research supports the potential of PA and physical fitness as stress-buffers. While empirical evidence from laboratory studies is conflicting to some extent, real-life studies showed promising findings, but are scarce. Further research is warranted to elaborate previous findings with a comprehensive methodology in externally valid conditions. While stress at work is a well-known real-life stressor, research on stress-buffering effects of PA and fitness, particularly in stressful occupations, is lacking.

Based on this background, the aim of the research presented here was to examine stress-buffering effects of PA and CRF in a real-life work environment. Following an empirical-analytical approach, traditional self-report measures were combined in a unique study design using new technologies (AA and EMA) in a longitudinal observational study. Exposure to chronic and acute work stress was examined alongside physiological and psychological health parameters twice within one year. PA was assessed over seven consecutive days via accelerometry, substantiated by a recently developed and validated questionnaire (Simple Physical Activity Questionnaire; SIMPAQ). CRF was objectively measured with the submaximal Åstrand cycling test. Cardiometabolic risk factors (including MetS) were assessed in a laboratory alongside of psychological health outcomes (i.e. burnout, and sleep health) using validated and widely accepted instruments.

Chronic work stress was observed with two of the most widely applied work stress questionnaires based on the job demand and control (JDC) model (Karasek, 1979), as well as the effort-reward imbalance (ERI) model (Siegrist, Siegrist, & Weber, 1986). Occupational stress, as quantified with these models, has been shown to be related to decreased psychological wellbeing (i.e. burnout, anxiety, impaired sleep quality) and physiological health (i.e. coronary heart disease, musculoskeletal disease), as well as increased mortality risk (Kivimäki et al., 2002; Matthews, Gump, & Owens, 2001; Seiler, 2014; Siegrist & Dragano, 2008). Acute work stress was measured using smartphone-based Ecological Momentary Assessment, whereas physiological reactivity and recovery were captured using AA of HRV (Linden, Earle, Gerin, & Christenfeld, 1997). An overview of the study procedure is presented in the Appendix (see APPENDIX 2).

The candidate's accomplishments included creating the project idea to examine the research question. This constitutes the development of a study design, choice of methodology and instruments. The candidate further established a cooperation with the police corps of the canton Basel-Stadt in order to obtain an appropriate sample. Furthermore, the candidate prepared and convoyed the corresponding proposal to and approval of the local ethics committee. In the execution of the study, the candidate organized the recruitment (including video presentations, E-Learning materials, internal journals, and E-Mail), built and managed the infrastructure to execute the study in terms of data assessment (external laboratory) and secure data storage. Next to the assessment, storage, preparation and analysis of the data, the candidate coached and supervised study personnel for data assessment and optional lifestyle-coaching. The candidate generated five project related publications (three published, two under review), visualized and presented study results to the scientific community.

The contributions of all co-authors are listed in each publication except for publication 4. Flora Colledge, Uwe Pühse, and Markus Gerber co-authored publication 4 ("Stress-Buffering Effects of Physical Activity and Cardiorespiratory Fitness on Metabolic Syndrome: a Prospective Study in Police Officers"). Flora College assisted the data analysis and interpretation, wrote sections of the manuscript, and critically reviewed and revised the manuscript. Uwe Pühse and Markus Gerber made substantial contributions to the conception of the study, drafted sections of the manuscript, monitored the writing process, and reviewed the revised manuscript.

2. Aims and objectives

Psychosocial stress is a modern world risk factor for cardiovascular and mental ill-health. The general goal of the present doctoral research project was to examine the well-founded but understudied possibility of stress-buffering effects of PA and CRF. While previous studies showed inconsistencies that may be related to the artificiality of applied laboratory stressors, the present research project was conducted to provide new insights in realistic stress experiences. Therefore, the first aim (1) of this research endeavour was to test buffering effects of PA and CRF on the association between chronic work stress and cardiometabolic, as well as mental health. The second aim (2) was to test underlying mechanisms in terms of the CSA hypothesis. The use of personally meaningful real-life stressors assessed by EMA and AA was employed to increase external validity compared to previous research.

Using an empirical-analytical approach, a one-year prospective observational study was conducted in a sample of police officers. (1) The first aim was addressed by cross-sectional and prospective analyses of the association between chronic work stress and (cardiometabolic and mental) health factors, and the influence (interaction effects) of PA and CRF. Well established and widely applied traditional methods were used, primarily based on laboratory and self-report measurements. (2) Newer methodologies, based on EMA and AA, were used to address the second aim of testing underlying mechanisms. Individual differences in the psychophysiological stress response of the ANS were examined using multiple measurements of work stress experiences.

Hypotheses:

(1) Higher levels of PA and CRF are associated with improved cardiometabolic and mental health related to increased chronic work stress (Gerber et al., 2016; Gerber et al., 2010a; Gerber, Kellmann, Hartmann, & Pühse, 2010b).

(2) Higher levels of PA and CRF are associated with lowered physiological stress reactivity in acute work stress situations and improved recovery related to acute and chronic work stress (Hynynen, Konttinen, Kinnunen, Kyrolainen, & Rusko, 2011; von Haaren, Haertel, Stumpp, Hey, & Ebner-Priemer, 2015; von Haaren et al., 2016).

3. Publications

The research project cumulated five publications that were submitted to international peer-reviewed journals. Three of these publications were accepted, whereas two are currently under review. The publications will be presented in the following order:

3.1 Publication 1:

Validation of the applied physical activity questionnaire

3.2 Publication 2:

Validation of the applied burnout questionnaire

3.3 Publication 3:

Cross-sectional analysis on stress-buffering effects of cardiorespiratory fitness on cardiovascular and mental health

3.4 Publication 4:

Prospective analysis on stress-buffering effects of physical activity and cardiorespiratory fitness on metabolic syndrome

3.5 Publication 5:

Real-life analysis on the cross-stressor adaptation hypothesis

3.1 Publication 1: Validation of the applied physical activity questionnaire

Title:

The utility of two interview-based physical activity questionnaires in healthy young adults: Comparison with accelerometer data

Authors:

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Published in:

PLOS ONE, 2019, 13(9).

Publication available at:

https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0203525

PLOS | ONE

RESEARCH ARTICLE

The utility of two interview-based physical activity questionnaires in healthy young adults: Comparison with accelerometer data

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Citation: Schilling R, Schärli E, Fischer X, Donath L, Faude O, Brand S, et al. (2018) The utility of two interview-based physical activity questionnaires in healthy young adults: Comparison with accelerometer data. PLoS ONE 13(9): e0203525. https://doi.org/10.1371/journal.pone.0203525

Editor: Maciej S. Buchowski, Vanderbilt University, UNITED STATES

Received: March 13, 2018

Accepted: August 22, 2018

Published: September 7, 2018

Data Availability Statement: The datasets used and/or analysed during the current study are available on reasonable request from Ms. Nienke Jones (Nienke.jones@bs.ch; +41 61 268 13 54) via the Ethics Committee of Northwestern and Central Switzerland (EKNZ). At the time of obtaining ethical clearance for the present study from the EKNZ, and in line with Swiss laws, we stated that only authorized researchers who are directly involved in the present project will have access to the raw data. Accordingly, and in line with this statement,

Abstract

Background

Accurate assessment of physical activity is essential to determine the magnitude of the health-related benefits of regular physical activity. While physical activity questionnaires are easy to use, their accuracy in comparison to objective measures has been questioned. The purpose of the present study was to examine the utility of two interview-based questionnaires; a recently-developed instrument, the Simple Physical Activity Questionnaire (SIMPAQ), and the Seven Day-Physical Activity Recall (7DPAR).

Methods

Accelerometer data was collected in 72 university students (50% females). Telephone interviews were conducted to complete the SIMPAQ and the 7DPAR.

Results

Significant correlations ($p < .001$) were found between accelerometer-based moderate-to-vigorous physical activity (MVPA), the amount of self-reported moderate-to-vigorous exercise assessed via the SIMPAQ (*rho* = .49), and vigorous physical activity assessed via the 7DPAR (*rho* = .50). Exercise assessed via the SIMPAQ was significantly correlated with the vigorous physical activity score of the 7DPAR (*rho* = .56, $p < .001$). While participants needed three minutes less to complete the SIMPAQ ($p < .001$), participants tended to be more confident about the accuracy of the answers they provided on the 7DPAR ($p <$ 01).

Funding: The authors received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

Abbreviations: 7DPAR, Seven Day Physical Activity Recall; LPA, Light physical activity; MET, Metabolic equivalent of task; MPA, Moderate physical activity; MVPA, Moderate-to-vigorous physical activity; SIMPAQ, Simple Physical Activity Questionnaire; TST, Total sleep time; VPA, Vigorous physical activity.

Conclusions

These two questionnaire measures of physical activity performed similarly in a healthy young adult sample. The SIMPAQ can be completed in 15 minutes, which could be an advantage in settings where time for physical activity assessment is limited.

Background

To document the health-related benefits of regular physical activity and the health risks associated with a physically inactive lifestyle [1], it is essential for sports, exercise and health scientists to accurately assess physical activity [2, 3]. Reliable and validated tools are essential to measure prevalence rates, estimate risk ratios, monitor changes in physical activity levels, and to formulate public health recommendations for specific target groups [2, 4].

Although some researchers argued that doubly labeled water technique and accelerometers should be seen as the gold standard to assess physical activity [3, 5, 6], doubly labeled water only provides information about energy expenditure, without providing information about time spent in physical activity at different intensity levels or in different contexts. Moreover, this technique is expensive and complex, and thus not suited for epidemiological research or clinical settings, where information must often be obtained in a short timeframe to allow clinical recommendations to be made to patients [6]. While accelerometers are less expensive and more practical, they are unable to accurately measure activities such as rowing, biking, and weight lifting [6, 7]. Although combined with heart rate, accelerometers can provide more detailed information about physical activity participation, they are still not commonly used in clinical practice [7]. Most likely this is due to relatively high costs, the burden placed on the participants (because the device must be worn for several days), issues associated with compliance, and the need for skilled personnel to analyze the data [7, 8].

Physical activity questionnaires are easy to use, do not require significant financial investments from the investigator, do not require significant motivation or time from the participant, and data is immediately available [7]. This may explain why self-report measures are widely used in research and clinical practice [2]. Nevertheless, some questions have been raised about the validity of physical activity questionnaires [2, 3, 7]. Existing self-report instruments, such as the International Physical Activity Questionnaire (IPAQ), were developed for population surveillance, and in clinical settings may be considered too long to complete, or may lead to overestimates of participants' physical activity levels [9, 10]. Correlations with objective measures have frequently been found to be relatively modest, although statistically significant in the large scale studies in which they are typically evaluated [11]. Another widely used instrument, the Seven-Day Physical Activity Recall (7DPAR), does not assess sedentary behavior, and correlations with accelerometer data were moderate for most measures obtained and also may both over- or underestimate physical activity levels [11–13]. A brief, yet comprehensive instrument to assess physical activity behavior, the Simple Physical Activity Questionnaire (SIMPAQ) [10], was developed with the aim of more accurately assessing physical activity. The current exploratory study was undertaken to compare this new tool with existing questionnaires, and an objective measure of physical activity in a convenience sample of healthy young adults attending university to study exercise and health science. We examined the relationships between questionnaire measures of physical activity and the same measures obtained via accelerometry, and evaluated the inter-correlations between questionnaire measures. We also evaluated the time taken to complete each questionnaire, and subjective perceptions of the accuracy and ease of completing these measures.

Methods

Participants

Participants were recruited at the Department of Sport, Exercise and Health of the University of Basel, Switzerland. Power analysis (using G*Power 3.1 software) showed that at least 64 participants were needed to detect (one-tailed) correlations of $r \geq .30$ (alpha error: .05, power: .80) [14]. After having received detailed oral and written information about the study, 83 exercise and health science students (40 men, 43 women; 67 undergraduate, 16 graduate) provided written informed consent. One student dropped out, seven students had to be excluded because of technical reasons (accelerometer malfunction), and one accelerometer was lost. Furthermore, two students had to be excluded due to insufficient accelerometer wear-time (see below for more information). Thus, the final sample consisted of 72 students (36 men, 36 women).

Procedures

Students were informed about the study during a lecture in the spring term (April to May 2016). After providing informed consent, students who wished to take part in the study provided information about anthropometry and demographic background including gender, age, weight, height, living situation, relationship status, and health status. Participants were given an accelerometer (ActiGraph® wGT3X-BT, Actigraph, Pensacola, USA), and were instructed to wear the device for a minimum of seven and a maximum of 14 days. Instructions on the use of the accelerometer and non-wear time sheets were handed out to each participant to systematically document periods when they did not wear the accelerometer. They were asked to provide times for a telephone interview. The telephone interview included the Simple Physical Activity Questionnaire (SIMPAQ) [10] and the Seven Day-Physical Activity Recall (7DPAR) [15], and took place seven to 14 days after the accelerometer has been distributed. Random assignment was used to ensure that 50% of the participants first completed the SIMPAQ or the 7DPAR, respectively. Additionally, participants rated the intelligibility and convenience of the instruments, and provided an estimate about their confidence in the accuracy of their answers. Both the SIMPAQ and the 7DPAR referred to the previous seven days.

Prior to the data collection, the study protocol was approved by the local ethical review board (Ethics Committee of Northwestern and Central Switzerland: EKNZ; approval number: 2016/272), and the study was carried out in accordance with the ethical principles described in the Declaration of Helsinki. As an incentive, all students took part in a prize draw for ten cinema tickets (worth approximately 13 Euro each).

Measures

Accelerometry. Physical activity was objectively assessed with the ActiGraph® wGT3X-BT accelerometer, a light triaxial activity monitor. Evidence of the validity and reliability of this instrument to accurately capture physical activity has been documented previously [6].

The monitor was placed on a strap around the wrist of the non-dominant hand, and participants were asked to wear it continuously during the study period, except for activities taking place in water lasting longer than 30 minutes or taking place below one meter of water surface. Non-wear periods were reported on a non-wear time sheet.

The sample rate was 30 Hz. Recordings were saved as raw data files and analyzed with the ActiLife Software (Version 6.13.2). Data were summed and stored in 60 seconds epoch lengths. Daily summed minute-by-minute data were categorized by cut-off values. ActiLife software does not provide validated cut-off values for wrist worn devices in adults. Therefore, we applied the recently developed cut-off values by Kamada et al. [16], which were <2000 vector magnitude counts per minute (VM cpm) for sedentary, 2000 to 7499 VM cpm for light physical activity, and ≥7500 VM cpm for moderate-to-vigorous physical activities [16]. In their validation study, Kamada et al. showed, in a sample of 94 US adults, that these cutoffs are best suited to minimize the mean differences of hip vs. wrist worn accelerometry (using the same instrument as we did in our study) over a 7-day measurement period. Physical activities listed on the non-wear time sheet were included as moderate physical activity if they also were identified as non-wear time by the ActiLife software [17]. Non-wear time was determined using the Troiano [18] algorithm with default settings. Following Clemente et al. [19], days with ≥10 percent of non-wear time were considered non-valid and excluded. To be included, participants had to have at least five valid days, including ≥4 valid weekdays and ≥1 valid weekend day (only considering the 7 days prior to the telephone interview). Sleep was calculated using the Cole-Kripke [20] algorithm with sleep period detection options provided by ActiGraph®. Weekly scores were obtained by dividing the sum of all valid days through the number of valid days, and then multiplying by seven. The following indices were examined (in min per week): sleep, sedentary activity, light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA). Moreover, the weekly number of steps was measured.

Simple Physical Activity Questionnaire (SIMPAQ). The SIMPAQ is a brief five-item tool, which comprehensively evaluates activity over the past seven days including time in bed, sedentary time, time spent walking, type and time spent in exercise, and time spent for other activities [10]. Assessed physical activity refers to all domains of activity, including leisure time, domestic, work and transport-related activities. The SIMPAQ captures a 24-hour period representative for the previous week. An additional sixth item (time spent standing) was added to the SIMPAQ in the present study, based on experience in this healthy young adult group obtained during pilot testing of the SIMPAQ, which took place before the official start of the data assessment and was carried out with three staff members of the Department of Sport, Exercise and Health at the University of Basel.

To ensure optimal translation, we rigorously followed the procedure set out by Brislin [21]. English items were translated into German, and then back-translated into English by an independent translator (see supporting information S1 Fig for the wording of German items, see www.simpaq.org for the English version of the instrument). The following indices were generated (in min/week): time in bed, sedentary time, time spent standing, time spent walking, other physical activities, and exercise.

Seven-Day Physical Activity Recall (7DPAR). The 7DPAR is a widely-used instrument to assess physical activity [13, 15]. Evidence regarding the validity and reliability of this instrument has been reported previously [13, 15]. The 7DPAR assesses physical activity day-by-day for the previous seven days. Participants are asked to first report time spent in bed and then time for physical activities with ≥10 min duration and at least moderate intensity (in the morning, afternoon and evening) [15]. The 7DPAR starts with the previous day, and then refers to prior preceding days. Participants were asked to classify the intensity of the reported activities into moderate, hard or very hard. In the following, hard and very hard intensity were considered as vigorous and very vigorous in the interest of uniformity and clarity. The interviewers also assessed breaks during the activities, which are then subtracted from total activity time. For each day, additional information about time spent in strength and flexibility training is assessed. The 7DPAR provides information about the following seven parameters (in min/

week): sleep, moderate physical activity (MPA), vigorous physical activity (VPA), strength training, and flexibility training.

Statistical analyses

All analyses were conducted with SPSS Statistics 23 for Windows (IBM Corporation, Armonk, USA). Throughout all analyses, the level of significance was set at $p \leq 0.05$. First, descriptive statistics were calculated to describe the characteristics of the sample and the level of self-reported and objectively assessed physical activity. Normality was tested with Kolmogorov-Smirnov test. As not all parameters were distributed normally, Spearman correlation analyses were computed to study pairwise associations between indicators of self-reported and objectively assessed physical activity (all referring to the 7 days prior to the telephone interview). Spearman correlations were also used to examine bivariate relationships between the SIMPAQ and 7DPAR variables. Repeated measures analyses of variance (rANOVAs) with one within-subject factor (SIMPAQ vs. 7DPAR) were used to find out whether mean scores in time necessary to complete the SIMPAQ and 7DPAR and their usability differed from each other. Univariate outliers, defined at ≥3 standard deviations from the mean, were identified, resulting in one outlier for the time needed to complete the SIMPAQ. Because exclusion of the outlier did not substantially influence the results, this case was included in the further statistical analyses. Following the recommendations of Cohen [22], correlations of $rho < .30$ were considered small, with $rho = .30$ to .50 as medium and $rho > .50$ as large.

Results

Sample characteristics

Of the 72 participants included in the analyses, 36 answered the SIMPAQ first, and 36 answered the 7DPAR first. Males and females were both equally represented in the sample (36 each), with 18 males and 18 females first completing the SIMPAQ or 7DPAR, respectively. Most of the participants reported that they are physically healthy ($n = 69$, 96%), whereas 3 participants (4%) indicated that they currently had an injury, which prevented them from running for 15 minutes. Fifty-six participants (78%) were undergraduate students, 16 (22%) were master's students. The average age of the participants was 22.6±2.2 years, ranging from 19 to 29 years. The mean height and body weight were 180.1±6.5 cm and 77.3±8.2 kg for men, and 168.9±5.8 and 62.1±4.6 for women, respectively. The mean body mass index (BMI) was 22.5 ±2.3 kg/m^2 and the mean number of steps was 14075±2879 per day.

Descriptive results for physical activity

Descriptive statistics for self-reported physical activity and accelerometer-based data are presented in Table 1. When the six activities assessed in the SIMPAQ were summed up (sleep, sedentary, standing, walking, other activities, exercise), the mean score was 23.3±1.4 hours (range: 17.3 to 25.2 hours), which corresponds well with the target 24-hour period.

Correlations between accelerometer data and self-reported physical activity

Simple Physical Activity Questionnaire (SIMPAQ). Spearman correlation coefficients were calculated between the SIMPAQ and accelerometer data. As shown in Table 2, relatively hgh correlations were found between self-reported exercise and objectively assessed MVPA ($rho = .49$, $p < .001$) and number of steps ($rho = .56$, $p < .001$). Moreover, weak-to-moderate positive correlations were found for self-reported and objectively assessed sedentary time ($rho = .26$, $p < .05$) and time spent in bed/sleep ($rho = .35$, $p < .01$).

Table 1. Descriptive statistics for anthropometric measures and physical activity.

Variable	*M*	*SD*	Range	Skewness	Kurtosis	K-S
Age in years	22.5	2.5	19–29	1.12	0.91	0.16***
Height (cm; all participants)	174.5	9.4	157–193	0.13	-0.84	0.11*
Men	180.1	6.5	167–193	-0.28	-0.28	0.13
Women	168.9	5.8	157–180	0.38	0.42	0.20
Weight (kg; all participants)	68.7	11.2	52–90	0.42	-0.97	0.15**
Men	75.3	8.2	61–90	-0.07	-0.70	0.20
Women	62.1	4.6	52–75	0.72	1.84	0.09
BMI ($kg*m^{-2}$)	22.5	2.3	18.02–29.05	0.73	1.04	0.06
SIMPAQ	***M***	***SD***	**Range**	**Skewness**	**Kurtosis**	**K-S**
Time in Bed (min/week)	3479.1	446.2	2310.0–5355.0	0.67	3.82	0.14**
Sedentary Time (min/week)	3369.9	953.8	605.0–5775.0	-0.33	0.55	0.08
Time Spent Standing (min/week)	962.5	569.5	140.0–2730.0	1.02	1.08	0.18***
Time Spent Walking (min/week)	795.5	603.2	70.0–3255.0	1.83	4.20	0.19***
Other Physical Activities (min/week)	365.1	306.4	0.0–1575.0	1.56	2.68	0.24***
Exercise (min/week)	775.6	414.2	0.0–2070.0	0.65	0.43	0.08
7DPAR	***M***	***SD***	**Range**	**Skewness**	**Kurtosis**	**K-S**
Sleep (min/week)	3375.5	345.0	2100.0–4830.0	0.39	5.06	0.07
MPA (min/week)	461.0	337.4	0.0–1530.0	1.10	0.74	0.14**
VPA (min/week)	499.9	348.6	0.0–1515.0	0.73	-0.06	0.10*
Strength Training (min/week)	75.8	83.8	0.0–360.0	1.58	1.98	0.21***
Flexibility Training (min/week)	27.7	42.5	0.0–260.0	2.87	11.83	0.26***
Accelerometer	***M***	***SD***	**Range**	**Skewness**	**Kurtosis**	**K-S**
Sleep (min/week)	3131.2	321.8	2044.0–3937.0	-0.26	1.39	0.08
Sedentary Time (min/week)	4177.9	627.7	3140.8–6210.5	0.93	1.16	0.09
LPA (min/week)	2601.0	389.7	1573.0–3777.0	0.18	0.69	0.07
MVPA (min/week)	653.7	277.6	228.0–1565.0	0.91	0.91	0.10
Steps (number/week)	98527.4	20149.9	15345.0–139006.0	-0.97	3.04	0.09

Notes: kg = kilograms. m = meters. min = minutes. MPA = Moderate physical activity. VPA = Vigorous physical activity. LPA = Light physical activity. MVPA = Moderate-to-vigorous physical activity. SIMPAQ = Simple Physical Activity Questionnaire. 7DPAR = Seven Day Physical Activity Recall. Accelerometer: ActiGraph® WgT-3X. K-S = Kolmogorov-Smirnov Test.

*$p < .05$.

**$p < .01$.

***$p < .001$.

https://doi.org/10.1371/journal.pone.0203525.t001

Seven-Day Physical Activity Recall (7DPAR). Relatively high correlations were found between self-reported vigorous physical activity and accelerometer-based MVPA (*rho* = .50*p* < .001) and number of steps (*rho* = .54, *p* < .001). A moderate-to-strong correlation was found between objectively and self-reported sleep (*rho* = .48, *p* < .001)

Correlations between self-report physical activity questionnaires

Spearman correlations were also computed between the measures derived from the SIMPAQ and the 7DPAR. Results are presented in Table 3. Most importantly, a relatively strong correlation was found between the exercise score of the SIMPAQ and the VPA score of the 7DPAR (*rho* = .56, *p* < .001).

Table 2. Spearman correlations between subjective measures and accelerometer data for all participants ($N = 72$).

Variable	Accelerometer				
	Sleep	Sedentary Time	LPA	MVPA	Steps
SIMPAQ					
Time in Bed (min/week)	.35**	-.02	-.01	-.06	-.25*
Sedentary Time (min/week)	-.07	.26*	-.31**	-.29*	-.46***
Time Spent Standing (min/week)	-.03	-.08	.09	.02	.03
Time Spent Walking (min/week)	-.13	.05	.19	.00	.29*
Other Physical Activities (min/week)	-.14	.11	-.02	-.02	.25*
Exercise (min/week)	-.06	-.29*	.06	.49***	.56***
7DPAR					
Sleep (min/week)	.48***	-.08	-.13	-.06	-.17
MPA (min/week)	-.12	-.22	.34**	.12	.21
VPA (min/week)	.10	-.28*	.11	.50***	.54***
Strength Training (min/week)	.00	-.10	.04	.09	-.01
Flexibility Training (min/week)	-.13	-.09	.21	.26*	.12

Notes: min = minutes. MPA = Moderate physical activity. VPA = Vigorous physical activity. LPA = Light physical activity. MVPA = Moderate-to-vigorous physical activity. SIMPAQ = Simple Physical Activity Questionnaire. 7DPAR = Seven Day Physical Activity Recall. Accelerometer: ActiGraph® WgT-3X.

*$p < .05$.

**$p < .01$.

***$p < .001$

https://doi.org/10.1371/journal.pone.0203525.t002

Usability of the SIMPAQ and 7DPAR

As shown in Table 4, significantly less time was needed to complete the SIMPAQ than the 7DPAR (15.0 min ± 6.1 vs. 18.1 min ± 6.1, $p < .001$). Participants rated the 7DPAR as slightly

Table 3. Spearman correlations between subjective measures.

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SIMPAQ										
1. Time in Bed (min/week)	-									
2. Sedentary Time (min/week)	-.18	-								
3. Time Spent Standing (min/week)	-.16	-.19	-							
4. Time Spent Walking (min/week)	-.13	-.40**	.10	-						
5. Other Physical Activities (min/week)	-.17	-.19	-.07	.25*	-					
6. Exercise (min/week)	-.21	-.15	-.07	-.07	.01	-				
7DPAR										
7. Sleep (min/week)	.46***	-.10	-.05	.00	-.18	-.11	-			
8. MPA (min/week)	-.01	-.16	.14	.28*	.08	.07	.08	-		
9. VPA (min/week)	-.09	-.32**	-.25*	.03	.15	.56***	-.08	-.08	-	
10. Strength Training (min/week)	.05	-.03	-.20	-.10	.11	.08	.01	-.01	.17	-
11. Flexibility Training (min/week)	-.09	-.07	-.16	-.16	.10	.25*	-.12	-.03	.13	.18

Notes: min = minutes. MPA = Moderate physical activity. VPA = Vigorous physical activity. MVPA = Moderate-to-vigorous physical activity. SIMPAQ = Simple Physical Activity Questionnaire. 7DPAR = Seven Day Physical Activity Recall. Accelerometer: ActiGraph® WgT-3X.

*$p < .05$.

**$p < .01$.

***$p < .001$.

https://doi.org/10.1371/journal.pone.0203525.t003

Table 4. Comparison of the usability of the SIMPAQ and 7DPAR.

Variable	Overall (N = 72)		SIMPAQ first (n = 36)		7DPAR first (n = 36)		Instrument			Order of administration			Instrument x Order of administration		
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2
Time needed to complete the SIMPAQ	15.0	6.1	16.4	7.3	13.6	4.2	32.41	.000	.32	1.48	.228	.02	5.24	.025	.07
Time needed to complete the 7DPAR	18.1	6.1	18.3	6.0	17.9	6.3									
Intelligibility of SIMPAQ items	9.0	1.4	9.3	1.2	8.7	1.5	1.70	.197	.02	1.54	.219	.02	3.80	.055	.05
Intelligibility of 7DPAR items	9.1	1.1	9.2	1.2	9.1	1.1									
Convenience of SIMPAQ items	5.3	2.1	5.4	2.2	5.3	2.0	6.15	.016	.08	.02	.888	.00	.14	.713	.00
Convenience of 7DPAR items	5.8	1.6	5.8	1.7	5.8	1.5									
Confidence in accuracy of answers for SIMPAQ	6.3	1.6	6.4	1.4	6.1	1.8	11.75	.001	.15	.56	.458	.01	9.72	.003	.12
Confidence in accuracy of answers for 7DPAR	6.9	1.4	6.5	1.4	7.3	1.3									

Notes: SIMPAQ = Simple Physical Activity Questionnaire. 7DPAR = Seven Day Physical Activity Recall.

https://doi.org/10.1371/journal.pone.0203525.t004

easier to complete than the SIMPAQ ($p < .05$), and participants reported higher confidence in the accuracy of their answers when answering the 7DPAR ($p < .01$).

When participants first completed the 7DPAR, confidence in the accuracy of their answers was higher for the 7DPAR compared to the SIMPAQ ($p < .01$), whereas participants needed more time to complete the 7DPAR than the SIMPAQ ($p < .001$). When participants first completed the SIMPAQ, participants still needed less time to complete the SIMPAQ than the 7DPAR ($p < .05$).

Discussion

This study compared measures of physical activity obtained with two interview-based questionnaires in healthy young adults. The recently developed SIMPAQ was found to have adequate measurement properties and exercise-based physical activity derived from this tool was moderately to strongly correlated with objective accelerometer data. The SIMPAQ exercise score also correlated with VPA assessed via a previously well-validated self-report questionnaire (7DPAR). We also found that the SIMPAQ was completed in less time than the 7DPAR. Participants felt more confident in the accuracy of their answers when answering the 7DPAR. However, confidence in the accuracy of the answers only differed if participants had completed the 7DPAR first.

One of the novel features of the SIMPAQ is a focus on assessing all activities over a 24-hour period. In the current study, participants reported an average of 23 hours and 20 minutes of activities, suggesting a high degree of accuracy in estimating activity typical of a 24-hour period. We included an additional question to capture time spent standing, as in this healthy young adult population we found a relatively large amount of time was spent standing each day (approximately 2 hours and 20 minutes). Future research will be needed to establish whether this additional question would be equally useful in more sedentary or clinical populations.

Exercise assessed via the SIMPAQ was moderately to strongly associated with accelerometer-based data, with correlations ranging from $rho = .49$ (MVPA) to $rho = .56$ (number of steps). Thus, compared to a systematic review, in which Helmerhorst et al. [14] found Spearman correlations of $rho \approx .30$ in adults across several studies, stronger evidence for the criterion-validity of the two self-report questionnaires was found in the present sample. Several reasons exist why it is difficult to detect even stronger correlations between self-reported and objectively assessed physical activity. While accelerometry is a relatively feasible, and accurate method to assess physical activity [6], accelerometers measure the acceleration of the worn sensor, and therefore sometimes lead to misinterpretations with regard to particular types of physical activity. Some established limitations are the underestimation of walking and overestimation of jogging, the failure to detect resistance exercise and external work, and bicycle riding or the fact that the accelerometer must be taken off during some sport activities (e.g. swimming, during soccer games) [23]. Although speculative, the fact that no significant correlations were found for time spent walking and other physical activities with accelerometer-based MVPA might suggest that these activities do not reach moderate-intensity levels. Nevertheless, both walking and other physical activities were correlated with total number of accelerometer-based steps.

Similar correlations were observed for accelerometer data with the SIMPAQ and the 7DPAR, suggesting that criterion validity was acceptable for both interview-based instruments. Our findings are partly in line with prior research showing reasonably high correlations between the 7DPAR variables and accelerometer-based data, including indicators such as total energy expenditure, or time in MVPA [12, 13]. The finding that the MPA score of the 7DPAR was only weakly correlated with total accelerometer-based MVPA might be attributable to the fact that some self-reported physical activities might not have been captured as such by the Kamada et al. [16] algorithm for wrist-worn accelerometer data. Since few established algorithms exist for wrist-worn accelerometer data [24], we also used the more established algorithm of Freedson et al. [25] for hip-worn accelerometer data to examine our data. As shown in the supporting information (S1 Table), the correlations between the two questionnaires and the accelerometer data are similar (or slightly higher) for both the SIMPAQ and the 7DPAR. Data in S2 Table in the supporting information also shows reasonably high associations between the accelerometer scores for sedentary activity, MPA, VPA and MVPA, if data based on the Kamada et al. [16] and Freedson et al. [25] algorithm were correlated.

The SIMPAQ completion time was shorter than the 7DPAR, making it more efficient for both the investigator and the interviewee. While no remarkable differences were found for intelligibility and convenience, confidence in the accuracy of the given answers was higher for the 7DPAR. Although speculative, we assume that the latter finding is due to the characteristics of this sample. Thus, because exercise and health science students attend multiple exercise lessons throughout the week, using a day-to-day format as offered by the 7DPAR might increase their confidence that they accurately remembered all activities. Future research is needed to examine economy and usability of the SIMPAQ in less active samples who have lower levels of regular exercise participation.

In the present sample, accelerometer-based MVPA amounted to 654 min/week, while the amount of moderate-to-vigorous exercise assessed via the SIMPAQ was 776 min/week and the amount of VPA assessed via the 7DPAR 500 min/week. However, the question of which questionnaire more accurately estimates physical activity is difficult to answer because the SIMPAQ and 7DPAR contain different dimensions. In line with this notion, previous research was inconclusive whether physical activity assessed via interviews leads to an over- or underestimation of physical activity levels. For instance, a systematic review of studies validating the International Physical Activity Questionnaire [11] found incorrect estimates of total MVPA ranging from -28% to +173% for studies using accelerometry. Similarly, a recently published validation study of the 7DPAR [13] reported approximately 20% overestimation of MVPA. The reason why the self-report questionnaires can differ from the accelerometer data are multifold, including recall bias, incorrect perceptions of intensity of physical activity, interviewer effects, social desirability, limited compliance in wearing accelerometer devices, or problems of accelerometers to accurately assess all physical activities [26]. These issues notwithstanding, the present study showed that the SIMPAQ is relatively well-suited to capture activities across a 24-hours period, which might lead to more realistic physical activity estimates compared to other self-report instruments.

The strengths of this study were that questionnaires were applied in a counter-balanced order during the telephone interview, an equal number of men and women was included, relatively strict non-wear time limitations were applied, and dropout and exclusion rates were low.

Despite these advantages, the present study has certain limitations. First, the sample consisted of highly active, generally healthy university students, which is a particular group in relation to their commitment towards physical activity and sport. Although the SIMPAQ can be used in any population, the main idea behind the development of the SIMPAQ was to provide a simple self-report measure to assess physical activity in populations at high risk of sedentary behavior, such as people with psychiatric disorders [10]. Therefore, the validity of the SIMPAQ needs to be established in these specific target groups. Second, as reported above, the correlations between the SIMPAQ and 7DPAR may be positively biased, because the instruments were completed sequentially. Third, to increase compliance, participants were asked to wear accelerometers on the wrist [27]. While some argued that the wrist-worn accelerometers lead to less accurate (mostly lower) estimates of physical activity compared to waist- or back-worn devices [28, 29], others found only minor differences due to wear locations [27, 30], or indicated that sleep detection is inaccurate if the devices are worn around the hip [31, 32]. Specifically, McMinn et al. [28] found that the selection of the 'worn on wrist' option leads to a systematic underestimation of energy expenditure. We therefore decided not to select the 'worn on wrist' option when analyzing the data. Fourth, another possible limitation associated with the scoring of the accelerometers is related to the epoch length. Although not systematically studied in adults, research on children indicates that an epoch length of 60 seconds might underestimate participants' VPA counts [29].

Conclusions

The present study found that two interview-based questionnaire measures of physical activity resulted in similar findings in healthy young adults. The recently developed SIMPAQ proved to take three minutes less to complete than the 7DPAR, which could be an advantage in settings where time for physical activity assessment is limited. Research is currently underway to validate the SIMPAQ in more sedentary populations.

Supporting information

S1 Fig. Wording of the German version of the SIMPAQ used in the present study.
(DOCX)

S1 Table. Spearman correlations between subjective measures and accelerometer data.
(DOCX)

S2 Table. Bivariate correlations between accelerometer data using the Freedson et al. or Kamada et al. algorithm.
(DOCX)

Acknowledgments

We thank Flora Colledge (University of Basel, Switzerland) for proofreading the manuscript.

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3.2 Publication 2: Validation of the applied burnout questionnaire

Title:

Psychometric Properties and Convergent Validity of the Shirom-Melamed Burnout Measure in Two German-Speaking Samples of Adult Workers and Police Officers

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Published in:

Frontiers in Psychiatry, 2019, 10, 536.

Publication available at:

https://www.frontiersin.org/articles/10.3389/fpsyt.2019.00536/full frontiers in Psychiatry

ORIGINAL RESEARCH
published: 02 August 2019
doi: 10.3389/fpsyt.2019.00536

Psychometric Properties and Convergent Validity of the Shirom–Melamed Burnout Measure in Two German-Speaking Samples of Adult Workers and Police Officers

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OPEN ACCESS

Edited by:
Drozdstoy Stoyanov Stoyanov, Plovdiv Medical University, Bulgaria

Reviewed by:
Nicola Magnavita, Catholic University of the Sacred Heart, Italy
Stanislava Harizanova, Plovdiv Medical University, Bulgaria

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Specialty section:
This article was submitted to Psychopathology, a section of the journal Frontiers in Psychiatry

Received: *17 April 2019*
Accepted: *10 July 2019*
Published: *02 August 2019*

Citation:
Schilling R, Colledge F, Brand S, Ludyga S and Gerber M (2019) Psychometric Properties and Convergent Validity of the Shirom–Melamed Burnout Measure in Two German-Speaking Samples of Adult Workers and Police Officers. Front. Psychiatry 10:536. doi: 10.3389/fpsyt.2019.00536

Burnout is considered an occupation-related psychological syndrome consisting of emotional, physical, and cognitive exhaustion. To assess dimensions of burnout, the Shirom–Melamed Burnout Measure (SMB*M*) is widely used, but its validity and reliability have rarely been examined in adult samples. The aim of this study is to examine the psychometric properties of the German version of the SMB*M* in two independent samples of adults. In total, 311 adult workers and 201 police officers completed the SMB*M*, and questionnaires related to perceived stress and mental well-being. Descriptive statistics, internal consistency, convergent validity, and factorial validity were assessed for both samples, separately for male and female participants. The German SMB*M* had adequate psychometric properties and sufficient convergent validity. In confirmatory factor analyses, we found a good fit for both the first- and second-order model. Furthermore, measurement invariance across gender was observed in both samples. Although the SMB*M* is a popular instrument among burnout researchers, this study demonstrates for the first time that the SMB*M* can be considered a valid and reliable tool to assess burnout symptoms in both male and female adults and across different professional groups. Furthermore, with its 14 items, the SMB*M* is a succinct and economic self-assessment tool for symptoms of burnout.

Keywords: burnout, validation, psychometric properties, internal consistency, mental health, stress

INTRODUCTION

Burnout can be defined as an occupational syndrome consisting of emotional, physical, and cognitive exhaustion (1). While there is broad consensus that people with burnout require medical and psychiatric treatment, there has been constant debate as to whether burnout should be considered a specific and well-defined psychiatric disorder, an epiphenomenon of a major depressive disorder (ICD-10: F33.xx), an adjustment disorder (ICD-10: F43.xx) (2–7), or a form of chronic fatigue syndrome (ICD-10: G93.3). Bianchi et al. (8) argue that there is such a strong overlap between burnout and depression that burnout should not be considered as a specific job-related phenomenon, but rather as a depressive condition. However, others argue that the two constructs are distinct (9) and that burnout syndrome should be given the status of an occupational disease (10, 11). Currently, there are no conclusive diagnostic criteria (11, 12), and to date, the condition is not included in the Diagnostic and Statistical Manual of Mental Disorders (5th Edition) (DSM 5) (13). In the 11th version of the International Classification of Diseases (ICD-11), however, "burnout" is classified under QD85 and is defined as "a syndrome conceptualized as resulting from chronic workplace stress that has not been successfully managed" (see https://icd.who.int/browse11/l-m/en#/http://id.who.int/icd/entity/129180281). The ICD-11 definition highlights that burnout is a work-related phenomenon and thus not suitable for the description of experiences in other life domains.

The Swedish Health System recognizes burnout as a psychiatric disorder; therapeutic interventions and sick leave for affected individuals are standard treatment forms (14, 15). Moreover, a recent Europe-wide study concludes that 9 of 23 European countries currently consider acknowledging burnout as an occupational disease (16) [see also Refs. (10, 11, 17)]. Irrespective of diagnostic issues, we observe that burnout is a serious public health problem and therefore a cause for concern for policy makers, patients, and health insurance organizations (18).

To assess dimensions of burnout, the Maslach Burnout Inventory (MBI) is the most widely used instrument (19, 20). Maslach et al. (21) defined burnout as a (multidimensional) psychological syndrome consisting of emotional exhaustion, depersonalization/cynicism, and reduced personal accomplishment. Consequently, burnout is often considered synonymous with the definition provided by Maslach and colleagues (21–23). This also holds true for the new ICD-11 definition, where burnout is characterized by three dimensions, namely, "the feelings of energy depletion or exhaustion, increased mental distance from one's job, or feelings of negativism or cynicism related to one's job, and reduced professional efficacy." Nevertheless, the theoretical and scientific basis of the MBI has been questioned (19, 20, 24), especially in light of the fact that the three burnout dimensions were not deducted theoretically but are the result of exploratory factor analysis. In addition, it has been argued that the depersonalization/cynicism and reduced personal accomplishment subscales do not adequately represent the core of the burnout construct.

By contrast, Shirom, Melamed, and colleagues took the basic tenets of the Conservation of Resources (COR) theory (25, 26) into consideration. The resulting definition of burnout included an individual's feeling of being emotionally exhausted, physically fatigued, and cognitively worn-out (18, 27). Briefly, the COR theory assumes that people have a basic motivation to obtain, retain, and protect the resources that they value (28, 29). Accordingly, the chronic depletion of an individual's energetic resources following prolonged exposure to emotionally charged demands has been identified as the unique content of the burnout construct (30–32). More specifically, physical fatigue refers to an individual's feelings of tiredness and low levels of energy in carrying out daily tasks at work (or in general life) (p. 330) (27). Emotional exhaustion, on the other hand, describes the interpersonal aspect of burnout, "namely, feeling that one lacks the energy needed to invest in relationships with other people at work" (p. 330) (27). Finally, cognitive weariness describes the phenomenon of slower thinking and impaired mental agility. Melamed et al. (27, 31, 33) further hypothesized that this definition of burnout is distinct from a temporary state of fatigue, which generally disappears after a reasonable period of rest. Furthermore, Lundgren-Nilsson et al. (20) claimed that "this conceptualization of burnout has been proven useful, not only to measure burnout in working populations, but also in clinical populations of patients seeking medical care due to stress-related exhaustion" (p. 1).

Using Shirom and Melamed's (18, 27) definition of burnout, research has shown associations between burnout and both physiological and psychological health outcomes. Physiologically, higher burnout scores are associated with increased cardiovascular risk factors, including increased fasting glucose and cholesterol levels (31, 34–36), increased cortisol levels throughout the day (33), an elevated cortisol awakening response (37), increased leukocyte adhesiveness (32), increased inflammatory markers (35, 38), increased risk of developing type 2 diabetes (39, 40), increased risk of musculoskeletal pain (41), and a higher likelihood of infertility (42). As regards psychological dimensions, data from vocational students and adult workers have shown that higher burnout levels are associated with reduced life satisfaction and quality of sleep (33, 43, 44). Similarly, significant associations have been found between burnout and depression, although the level of overlap varied considerably (38, 45–48). Moreover, in the clinical setting, Glise et al. (14) showed that among individuals with diagnosed job-related exhaustion disorder, ~90% displayed severe burnout scores. Finally, a multimodal treatment approach has been shown to lead to a reduction of burnout symptoms in the majority of patients (15, 49).

The Shirom–Melamed Burnout *Questionnaire* (SMBQ) was devised to assess this COR-inspired definition of burnout. The questionnaire consists of eight items to assess symptoms of physical fatigue and emotional exhaustion (e.g., "I feel physically exhausted.") and four items to assess tension (e.g., "I am tense.") and listlessness (e.g., "I feel sleepy."), respectively (30, 31). A distinction between tension and listlessness was made because the development of burnout was originally considered as a two-phase process, with tension being predominant in the early stages when active and direct coping strategies are employed to enhance and protect resources, and listlessness being characteristic of the more advanced stages when indirect and inactive coping prevails and burnout becomes more closely linked with apathy and depression (31). Answer options on the SMBQ 7-point Likert scale range from 1 (almost never) to 7 (almost always), with higher scores reflecting a higher degree of self-rated burnout. Norlund et al. (50) employed the SMBQ among a sample of 1,000 participants representative of the general population in Northern Sweden: Using an (arbitrary) cut-off of ≥4.0, the authors showed that 9.9% of all men and 15.9% of all women reported high burnout levels, while the level of burnout decreased with age across both genders. Furthermore, in another epidemiological study with 2,694 health care and social insurance workers from the Gothenburg region (51), the prevalence of employees reporting high burnout (≥4.0) was considerably higher (24%), indicating that burnout prevalence rates might vary strongly as a function of age, gender, job, and sample.

To cope with some methodological issues, the Shirom–Melamed Burnout *Questionnaire* (SMBQ) was revised to form the 14-item Shirom–Melamed Burnout *Measure* (SMB*M*). In contrast to the SMBQ, the SBM*M* is composed of three subscales, namely, emotional exhaustion, physical fatigue, and cognitive weariness (32, 33). While the items of the first two dimensions were identical to those of the SMBQ, items related to cognitive weariness were added to assess the cognitive component of burnout (e.g., "My head is not clear." or "It is hard for me to think about complicated things."). This extension seemed plausible as cognitive weariness has been defined as a core dimension of burnout (18, 27).

Both the SMB*Q* and SMB*M* are employed in burnout research (see literature presented above), and the SMB*M* has been translated from English into several languages, including Czech, French, German, Hebrew, Polish, Russian, and Spanish (see www.shirom.org/arie/index.html#). However, the validity and psychometric properties of these translations have not been evaluated systematically. What is known so far is that the SMB*Q*/SMB*M* overall indices and subscales have satisfactory internal consistency (14, 19, 24, 30–31, 32, 37, 40, 52), with Cronbach's alpha values generally exceeding accepted standards ($\alpha \geq 0.70$) (53). Furthermore, the SMB*Q*/SMB*M* have a relatively high time stability, with correlations of $r \geq 0.50$ across follow-up periods of several years (39, 40, 54). With regard to the convergent validity, evidence suggests that burnout is closely associated with individuals' chronic stress exposure (19, 50, 52, 55–57). Moreover, the SMB*M* and other burnout measures such as the MBI were reasonably correlated with each other. As expected, particularly high correlations were observed between the SMB*Q*/SMB*M* and the emotional exhaustion subscale of the MBI (19, 35). As reported previously, several longitudinal studies have confirmed that the SMB*Q*/SMB*M* instruments were able to predict specific physiological variables in the expected directions (e.g., cardiovascular disease risk factors, inflammatory biomarkers), thus underscoring the predictive validity of these questionnaires (27). Evidence has also suggested that at least moderate correlations exist between the SMB*Q*/SMB*M* and symptoms of depression and anxiety (45, 52). Preliminary results support the factorial validity of the SMB*M*: In a study with 717 Chinese hospital nurses, Qiao and Schaufeli (23) showed that a three-factor model achieved sufficient model fit, with the three factors being strongly correlated (r = 0.61–0. 73, $p < 0.001$). Moreover, in a sample of 214 Canadian employees, Sassi and Neveu (24) observed that a three-factor model resulted in a better model-fit than a one-factor solution. Again, a good fit was found between the three-factor model and the empirical data. Moreover, the three factors were moderately-to-strongly associated with each other (r = 0.38–0.58, $p < 0.001$). Finally, Lundgren-Nilsson et al. (20) used both Confirmatory Factor Analysis (CFA) and Rasch analysis to assess the construct validity of the SMB*Q*; their analyses showed that after removal of the items representing the tension subscale, an 18-item version of the SMB*Q* satisfied modern measurement standards. Most importantly, a cut-off of ≥4.40 for severe or clinically relevant burnout was suggested. With this cut-off, 83.4% of their clinical sample of patients suffering from job-related exhaustion disorder were placed above the cut, whereas 86.5% of the general population sample of health care and social insurance workers were categorized below the cut.

In summary, preliminary evidence supports the validity of the SMB*M*, while studies examining the psychometric properties and validity of the different language versions of the SMB*M* are still rare. To the best of our knowledge, only the French and Chinese versions of the SMB*M* have been examined systematically.

Given this background, the main purpose of the present study was to validate the German version of the SMB*M* across two different samples. We hold that the present study is important for several reasons: First, many scholars have used the SMB*M* during the last 25 years to assess burnout symptoms, and this holds true in German-speaking samples (44, 58, 59). Second, although it is well documented that men and women differ with regard to burnout prevalence (44, 50, 57), we are not aware of any study examining whether the psychometric properties of the SMB*M* apply equally across genders among adult workers.

Four hypotheses were formulated: First, we expected that women would show higher burnout scores than men (44, 50, 57). Second, we expected that adequate internal consistency would be found for the SMB*M* in both populations and both male and female. More specifically, we expected that all inter-item correlations would be ≥0.20. We also expected that Cronbach's alpha values would be ≥0.70. Finally, we expected that item-total correlations would be ≥0.30 (23, 24, 32). Third, we expected to find adequate convergent validity in male and female participants and across both study populations. That is, we hypothesized that the SMB*M* subscales and the SMB*M* overall index would be moderately to strongly correlated with perceived stress (positive correlation) (44, 45, 48). Fourth, with regard to factorial validity, we expected that a three-factor model would produce adequate model fit (23, 24) and that both a first- and second-order model would fit well with the empirical data (24). In line with previous research (23, 24), we expected good factor loadings (≥0.55) across all items on the corresponding factors [see Ref. (60)] and at least weak measurement invariance across genders (more information regarding types of measurement invariance is provided in the *Materials and Methods* section).

MATERIALS AND METHODS

Sample 1: Adult Workers

Participants and Procedures

The first study population was composed of adult workers who were recruited *via* exercise and health science students (N = 87) of the University of Basel, who took part in an introductory course in research methodology. Every student was asked to provide the names and email addresses of 6–12 people (no relatives) who would be willing to take part in an online survey. In order to obtain a broad sample, each student was asked to provide the names of a total of 12 persons from a variety of professional groups: a) with vocational education and training working in the primary (farming, forestry, hunting, mining, fishing) or secondary sectors (industry, construction industry), b) without higher education working in the tertiary sector (trade, transport, warehousing, hospitality, gastronomy, services), and c) with higher education working in the tertiary sector. For each of the three categories, students had to list one male and female person, and one person younger and one person older than 50 years. In total, the students suggested 756 potential participants (407 men, 349 women; on average 8.7 suggestions per student). Written informed consent was obtained from all participants, and the local ethics committee approved the study (EKNZ: 240/12). After two reminders, 311 adult workers completed the online survey (41.1% response rate).

Burnout

To measure symptoms of burnout, the participants answered the SMB*M* (32), which consists of 14 items that have been described in detail in the introduction section. The German version was downloaded from the homepage of Arie Shirom (www.shirom.org/arie/index.html; see **Supplementary online material**).

Perceived Stress

We employed the 10-item Perceived Stress Scale (PSS) (61) to measure participants' levels of perceived stress. The PSS consists of 10 items and assesses stress during the past month. Participants report the frequency with which they find their lives unpredictable, uncontrollable, and overwhelming (e.g., "During the last month, how often have you been upset because of something that happened unexpectedly?," "During the last month, how often have you felt that things were going your way?"). Answering options ranged from 1 (never) to 5 (very often). Higher scores are indicative of more pronounced subjective stress perceptions. The PSS proved to be a reliable und valid instrument in previous research (62, 63). In our population, we found a Cronbach's alpha of $\alpha = 0.75$.

Occupational Stress

We used the 11-item Job Content Questionnaire (JCQ) to assess an imbalance between demands and control at work (64). To assess job-related demands, participants answered five items on a 4-point Likert scale ranging from 1 (never) to 4 (often). For instance, we asked participants whether their job requirements include very fast or hard work or whether they have to accomplish large amounts of work. A sample item is: "My job requires me to work very hard." In addition, participants completed six items to assess their perceived level of control at work. A sample item is: "I have freedom to make decisions about my job." For each domain, we calculated a subscale score by summing up the values of each item, with higher scores being indicative of higher demands or control at work. We used the following formula to obtain the JDC ratio: job demand/(job control × 0.8333). In addition, we used the 16 items from the Effort-Reward Imbalance (ERI) questionnaire to assess job-related effort and reward (65). We assessed effort at work with five items and reward with 11 items, all of which were anchored on a 5-point Likert-scale. Items were completed in a two-step process. Participants first indicated whether they agreed or disagreed with the item content, describing a typical experience of their work situation. Items were scored 1 if participants did not experience a specific type of situation. If they did experience this type of situation, participants indicated how stressful each experience usually is for them, with response options ranging from 2 (not distressing) to 5 (very distressing). Sample items for the effort scale are: "I have a lot of responsibility in my job" or "I have many interruptions and disturbances in my job." Sample items for the reward scale are: "I receive the respect I deserve from my superior or a similarly relevant person." or "Considering all my efforts and achievements, my job promotion prospects are adequate." Items were summed to obtain subscale scores for the effort and reward domains, with higher scores reflecting higher effort or reward. Because of the unequal number of items, we used the following formula to generate the ERI ratio: effort/(reward × 0.4545). Evidence for the validity and reliability of this instrument has been presented previously (65).

Depressive Symptoms

We applied the Depression subscale of the Hospital Anxiety and Depression Scale (HADS) to measure self-perceived depressive symptoms (66). The depression subscale of the HADS consists of seven items, asking participants about mood changes that may occur during the course of depression (e.g., "I still enjoy the things I used to enjoy."). This instrument was originally designed for nonpsychiatric populations. Answers were given on a Likert-scale with four response options, from 0 (never) to 4 (almost always). Previous investigations have shown that the HADS has good psychometric properties and can be considered a valid tool to assess depressive symptoms. Items were summed to obtain an overall index, with higher scores being indicative of higher depressive symptoms. The Cronbach's alpha was $\alpha = 0.71$ in our population.

Statistical Analyses

Univariate analyses of variance (ANOVA) were used to examine gender differences. Correlational analyses were used to examine homogeneity and total correlations of all items. Internal consistency was measured with Cronbach's alpha coefficient. Correlations were employed to test convergent validity. Finally, factorial validity was tested by means of CFA. Our expectation was that the 14 items would load on three different factors (six items on physical exhaustion, five items on cognitive weariness, and three items on emotional exhaustion). Accordingly, our three-factor model contained at total of 14 observed variables that were linked to three latent constructs. Maximum likelihood (ML) was applied to estimate the parameters. Moreover, we inspected multiple fit indexes to judge the fit between the empirical data and the theoretical model data (67). Simultaneous multiple group comparisons were used to test invariance of the measurement model across gender. As recommended by Byrne (68), good model fit is achieved if the normed fit index (NFI) is ≥0.95, the comparative fit index (CFI) is ≥0.95, the Tucker Lewis Index (TLI) is ≥0.95, and the root mean square error of approximation (RMSEA) is ≤0.05. As recommended by Comrey and Lee (60), standardized factor loadings should be interpreted as follows: ≥0.71 = excellent, ≥0.63 = very good, ≥0.55 = good, ≥0.45 = fair, and >0.32 = poor. CFA are performed with AMOS® 24 (IBM Corporation, Armonk NY, USA), all other analyses with SPSS® 22 (IBM Corporation, Armonk NY, USA). We compared the default model against a model which assumed configural (same pattern of fixed and free factor loadings across gender), weak (invariant factor loadings across gender), strong (invariant factor loadings and intercepts across gender), and strict (invariant factor loadings, intercepts, and unique factor variances across gender) measurement invariance in order to test measurement invariance across gender (69). We used $\Delta\chi^2$ to examine the fit of different models, with nonsignificant $\Delta\chi^2$-test scores indicating that the more restricted model fitted better with the empirical data.

RESULTS

Sample 1 was composed of 161 male and 150 female participants. The mean age was $M = 42.64$ years ($SD = 14.02$; range, 19–67 years). Participants reported a mean job experience of $M = 21.61$ years ($SD = 13.95$; range, 1–47 years). All participants were employed for at least 50% ($M = 88.01\%$; $SD = 17.87$; range, 50–100%), with 60.1% in full time employment. The sample had a mean body mass index (BMI) (height in cm/body weight in kg^2) of $M = 23.87$ ($SD = 3.6$), with 33.40% of the sample ($n = 104$) being classified as overweight (BMI ≥ 25). Moreover, 40.5% ($n = 126$) reported that they have children living at home, 1.9% ($n = 6$) had responsibility as a caregiver for a person in need of care, and 8.4% ($n = 26$) reported shift work. With regard to participants' highest level of education, one person (0.3%) finished compulsory school without additional training, 42.5% ($n = 132$) completed vocational education and training, 9.6% ($n = 30$) completed academic high school, and 47.6% ($n = 148$) completed higher education. Finally, 14.5% ($n = 45$) reported that they are smokers, whereas 1.9% ($n = 6$) reported taking antidepressant medication.

In sample 1, we found a mean score of the SMB*M* overall index of 2.42 ($SD = 1.00$) (**Table 1**). In total, 5.8% ($n = 18$) of the participants had a burnout score that can be deemed clinically relevant (≥4.40). We did not find significant gender differences with respect to any of the SMB*M* overall index and subscales (**Table 1**). A χ^2-test showed that a similar portion of women ($n = 9$, 6.0%) and men ($n = 9$, 5.6%) reported clinically relevant burnout symptoms, $\chi^2(1) = 0.03$, p = ns.

For the three SMB*M* subscales, the inter-item correlations were all above 0.20. Moreover, item-total correlations were all above the critical threshold of 0.40. In our sample, all Cronbach's alpha values were satisfactory (physical exhaustion = 0.92, cognitive weariness = 0.95, emotional exhaustion = 0.90, SMB*M* overall index = 0.95).

Regarding convergent validity (**Table 2**), we found a positive correlation between the SMB*M* overall index and the PSS sum score ($r = 0.56$, $p < 0.001$). If compared to the emotional exhaustion subscale ($r = 0.35$, $p < 0.001$), we found stronger associations between the PSS sum score and the physical exhaustion ($r = 0.54$, $p < 0.001$) and cognitive weariness subscales ($r = 0.49$, $p < 0.001$). The SMB*M* indices were also moderately and positively

TABLE 1 | Descriptive statistics for the two samples, test of gender differences, and bivariate correlations between the Shirom–Melamed Burnout Measure (SMB*M*) subscales and the overall SMBM index.

	Sample 1: Adult workers (*N* = *311*)						
	M	**SD**	**Range**	**Skewness**	**Kurtosis**	**ANOVA**	
Descriptive statistics						***F***	**η²**
Physical exhaustion	2.72	1.26	1–7	0.87	0.35	0.05	0.000
Cognitive weariness	2.43	1.16	1–6	0.88	0.33	0.88	0.003
Emotional exhaustion	1.80	0.86	1–6	1.36	2.21	1.20	0.004
Overall SMB*M* Index	2.42	1.00	1–6.21	1.00	0.77	0.22	0.001
Bivariate correlations	1.	2.	3.	4.			
1. Physical exhaustion	–	0.75***	0.54***	0.93***			
2. Cognitive weariness	0.69***	–	0.68***	0.93***			
3. Emotional exhaustion	0.47***	0.55***	–	0.74***			
4. Overall SMB*M* Index	0.92***	0.89***	0.68***	–			
	Sample 2: Police officers (*N* = 201)						
	M	**SD**	**Range**	**Skewness**	**Kurtosis**	**ANOVA**	
Descriptive statistics						***F***	**η²**
Physical exhaustion	2.84	1.25	1–7	0.80	0.45	7.31**	0.035
Cognitive weariness	2.48	1.17	1–6.60	0.84	0.31	2.38	0.012
Emotional exhaustion	1.90	0.95	1–5.67	1.20	1.33	0.11	0.001
Overall SMB*M* Index	2.51	0.99	1–6	0.86	0.70	4.11*	0.020
Bivariate correlations	1.	2.	3.	4.			
1. Physical exhaustion	–	0.67***	0.51***	0.92***			
2. Cognitive weariness	0.53***	–	0.57***	0.89***			
3. Emotional exhaustion	0.52***	0.54***	–	0.71***			
4. Overall SMB*M* Index	0.88***	0.84***	0.73***	–			

Correlations for male participants are listed above the diagonal, correlations for female participants below the diagonal.
$*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

TABLE 2 | Bivariate correlations between burnout symptoms, perceived stress, depressive symptoms, and overall mental distress.

	Physical exhaustion	Cognitive weariness	Emotional exhaustion	Overall SMB*M* Index
Sample 1: Adult workers (*N* = 311)				
Perceived stress (PSS)	0.54*** (0.54***/0.55***)	0.49*** (0.47***/0.52***)	0.35*** (0.39***/0.33***)	0.56*** (0.56***/0.56***)
Effort–Reward Imbalance (ERI)	0.42*** (0.41***/0.44***)	0.37*** (0.33***/0.40***)	0.35*** (0.27**/0.42***)	0.44*** (0.41***/0.47***)
Job Demand-Control Imbalance (JDC)	0.39*** (0.30***/0.47***)	0.34*** (0.27**/0.42***)	0.21*** (0.12/0.32***)	0.39*** (0.30***/0.48***)
Depressive symptoms (HADS-D)	0.50*** (0.48***/0.53***)	0.47*** (0.47***/0.47***)	0.38*** (0.32***/0.43***)	0.53*** (0.51***/0.55***)
Sample 2: Police officers (*N* = 201)	**Physical exhaustion**	**Cognitive weariness**	**Emotional exhaustion**	**Overall SMB*M* Index**
Perceived stress (PSS)	0.59*** (0.74***/0.47***)	0.44*** (0.53***/0.37***)	0.42*** (0.42***/0.44***)	0.59*** (0.71***/0.49***)
Effort–Reward Imbalance (ERI)	0.33*** (0.31***/0.41***)	0.24*** (0.33**/0.20*)	0.14+ (0.11/0.15+)	0.31*** (0.34**/0.33***)
Job Demand-Control Imbalance (JDC)	0.28*** (0.37**/0.23**)	0.32*** (0.34**/0.31***)	0.12+ (0.24*/0.04***)	0.31*** (0.40**/0.26***)
Overall mental distress (GHQ-12)	0.56*** (0.49***/0.59***)	0.55*** (0.57***/0.53***)	0.43*** (0.29*/0.54***)	0.62*** (0.57***/0.64***)

SMBM, Shirom–Melamed Burnout Measure; PSS, Perceived Stress Scale; ERI, Effort Reward Imbalance; JDC, Job Demands and Control; HADS-D, Hospital Anxiety and Depression Scale–Depression Subscale; GHQ12, 12-item General Health Questionnaire. Correlations for female (first value) and male participants (second value) are listed in brackets.
*+p < 0.10. *p < 0.05. **p < 0.01. ***p < 0.001.*

TABLE 3 | Goodness-of-fit indices and model comparison.

	First-order model					Second-order model				
Sample 1: Adult workers (*N* = 311)	**CFI**	**TLI**	**NFI**	**RMSEA**	***p*(Δχ2)**	**CFI**	**TLI**	**NFI**	**RMSEA**	***p*(Δχ2)**
Default model	0.96	0.95	0.93	0.06 (0.05, 0.07)	–	0.97	0.96	0.94	0.06 (0.05, 0.07)	–
+ Configural invariance across genders	0.96	0.95	0.93	0.06 (0.05, 0.07)	0.105	0.97	0.96	0.94	0.05 (0.04, 0.06)	0.852
+ Weak invariance across genders	0.96	0.95	0.93	0.06 (0.05, 0.07)	0.226	0.97	0.96	0.94	0.05 (0.04, 0.06)	0.449
+ Strong invariance across genders	–	–	–	–	0.000	0.97	0.96	0.93	0.05 (0.04, 0.06)	0.485
+ Strict invariance across genders	–	–	–	–	–	0.97	0.97	0.93	0.05 (0.04, 0.06)	0.263
Sample 2: Police officers (*N* = 201)	**CFI**	**TLI**	**NFI**	**RMSEA**	***p*(Δχ2)**	**CFI**	**TLI**	**NFI**	**RMSEA**	***p*(Δχ2)**
Default model	0.97	0.97	0.93	0.05 (0.04, 0.07)	–	0.98	0.97	0.93	0.05 (0.04, 0.06)	–
+ Configural invariance across genders	0.97	0.97	0.93	0.05 (0.04, 0.06)	0.438	0.98	0.97	0.93	0.05 (0.03, 0.06)	0.853
+ Weak invariance across genders	0.97	0.97	0.92	0.05 (0.04, 0.06)	0.190	0.98	0.97	0.93	0.05 (0.03, 0.06)	0.391
+ Strong invariance across genders	–	–	–	–	0.000	–	–	–	–	0.022
+ Strict invariance across genders	–	–	–	–	–	–	–	–	–	–

AGFI, adjusted goodness-of-fit index; CFI, comparative fit index; TLI, Tucker Lewis index; RMR, root mean square residual; RMSEA, root mean square error of approximation; NFI, Normed Fit Index.

correlated with the ERI ratio ($r = 0.35–0.44$, $p < 0.001$), the JDC ratio ($r = 0.21–0.39$, $p < 0.001$), and the depression subscale of the HADS ($r = 0.38–0.53$, $p < 0.001$).

Regarding factorial validity, we found a satisfactory model fit for the three-factor model for the first- and second-order model (**Table 3**). Configural and weak measurement invariance (invariant factor loadings) was supported across genders. The second-order model even supported strict measurement invariance. Factor loadings were very good (with all loadings being ≥0.63). The measurement coefficients for the three-factor models are displayed in **Figure 1**, both for female and male participants. We also found relatively strong associations between the SMB*M* subscales in the first-order model ($r = 0.51–0.76$, $p < 0.001$).

Sample 2: Police Officers

Participants and Procedures

Sample 2 consisted of 201 police officers who were recruited from a police force in a bigger city in the Northwestern, German-speaking part of Switzerland. All officers ($N = 980$, 290 female, 690 male) were invited to participate in a comprehensive health check [including a cardiorespiratory fitness test, 7-day actigraphy, smartphone-based 2-day assessment of work-related affect and stressors, anthropometry, measurement of fasting blood lipid and blood glucose, blood pressure assessment, a computerized cognitive test (facial emotion recognition), a functional movement screen, a lung function test, and an online survey focusing on stress and mental health]. The health check

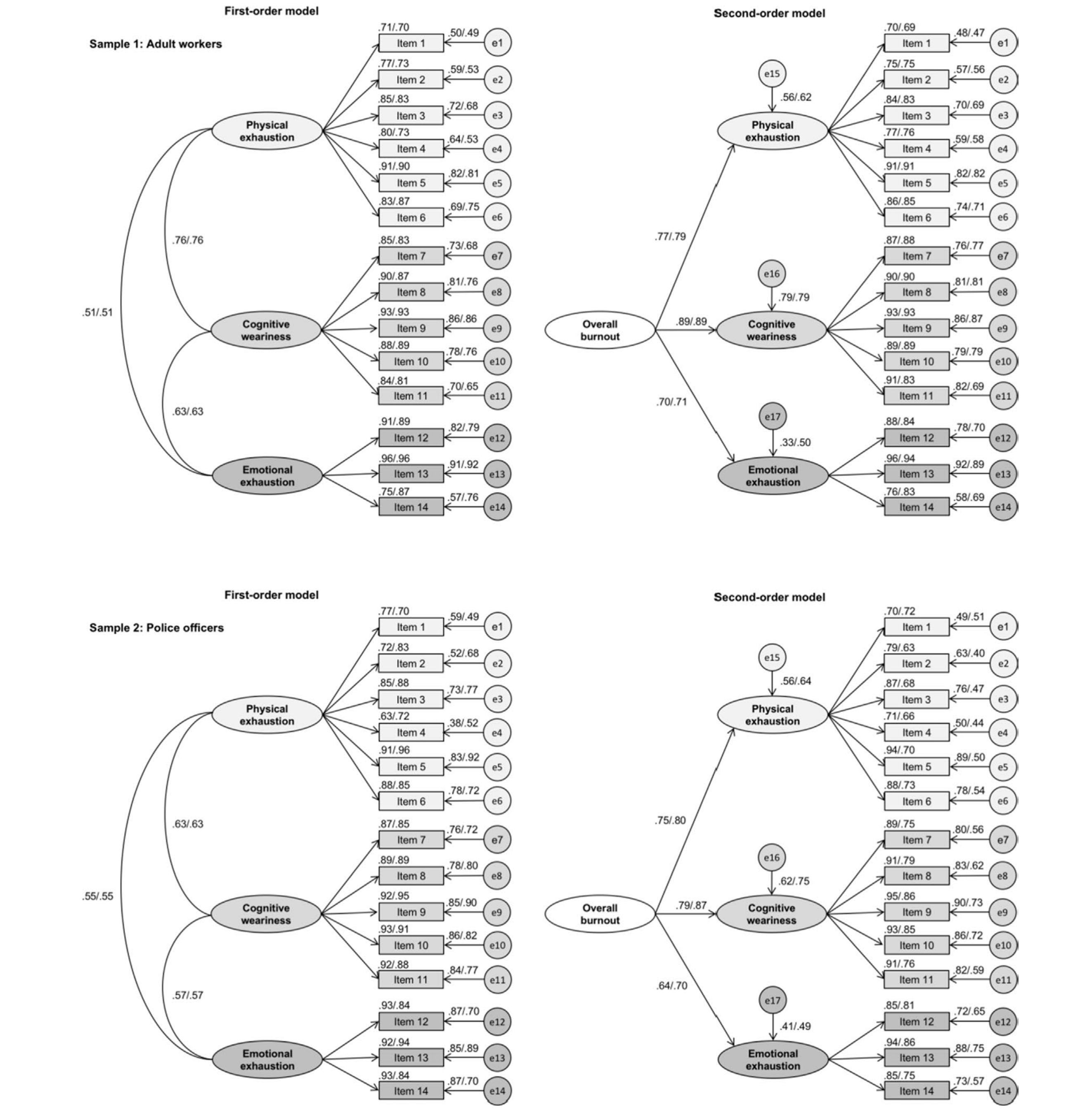

FIGURE 1 | Factor loadings for confirmatory factor analysis for female (first coefficient) and male participants (second coefficient), for first-and second-order models, separately for adult workers and police officers.

was advertised *via* intranet, video clips on the internal TV channel, printed flyers, and verbal information during team meetings. Detailed information was given to all interested officers (e.g., about the voluntary basis of participation, no negative consequences in case of nonparticipation, information about benefits and risk, information about measurements). Out of all 980 information recipients, 201 participated in the study (20.5% response rate). Data were assessed between December 2017 and April 2018. A personalized health profile was given to the officers after the completion of the data assessment as an incentive for participation. Moreover, all officers had the opportunity to participate in a voluntary lifestyle coaching. All participants provided written informed consent before data assessment. All procedures were in line with the ethical principles described in the Helsinki Declaration, and approval was obtained for the study by the local ethics committee (EKNZ: Project-ID: 2017-01477).

Burnout

As with sample 1 (adult workers), we used the 14-item SMB*M* to measure burnout symptoms.

Perceived Stress

As with sample 1 (adult workers), police officers' self-perceived levels of stress were assessed with the four-item PSS.

Occupational Stress

As for sample 1, occupational stress was assessed with the 11-item Job Content Questionnaire (JCQ) and the 16-item Effort-Reward Imbalance (ERI) questionnaire.

Overall Mental Distress

To assess overall mental distress, all officers filled in the German version of the General Health Questionnaire (GHQ-12) (70; 71). Participants were asked to rate their mental well-being, with reference to the previous week. Response options on a 4-point Likert scale ranged from 0 (not at all) to 3 (much more than usual). A sum score was calculated (from 0 to 36), with higher scores being reflective of higher levels of mental distress. Although no standard clinical cut-offs exist for the GHQ-12, researchers have used the following categories to successfully establish links between the GHQ-12 and mortality (if response options 0 + 1 = 0, and 2 + 3 = 1): asymptomatic (0), subclinically symptomatic (1–3), symptomatic (4–6), and highly symptomatic (7–12) (72, 73).

Statistical Analyses

We performed the same statistical analyses as with sample 1.

RESULTS

Sample 2 was composed of 72 female and 129 male participants. The mean age was M = 38.55 years (SD = 10.13; range, 22–62 years). Participants reported a mean job experience of M = 12.77 years (SD = 8.8; range, 0–37 years). All participants were employed for at least 30% (M = 92.08%; SD = 18.21; range, 30–100%), with 79.6% having a full-time employment. The sample had a mean body mass index (height in cm/body weight in kg^2) of M = 25.77 (SD = 3.63), with 52.7% of the sample (n = 106) being classified as overweight (BMI ≥ 25). Moreover, 43.3% (n = 87) reported that they have children living at home, 3.0% (n = 6) had responsibility as a caregiver for a person in need of care, and 48.3% (n = 97) reported shift work. With regard to participants' highest level of education, 2.0% (n = 4) finished compulsory school without additional training, 50.7% (n = 102) completed vocational education and training, 7.5% (n = 15) completed an academic high school, and 39.8% (n = 80) completed higher education. Finally, 18.4% (n = 37) reported that they are smokers, whereas 10.0% (n = 20) reported taking antidepressant medication.

In the total sample, we found a score for the SMB*M* overall index of 2.51 (SD = 0.99) (**Table 1**). Moreover, 5% (n = 9) of the participants had burnout levels above the cut-off for clinically relevant burnout symptoms (≥4.40). In comparison to male participants, female officers scored higher with regard to physical exhaustion (women: M = 3.15, SD = 1.30; men: M = 2.66, SD = 1.19) and the overall SMB*M* index (women: M = 2.70, SD = 1.00; men: M = 2.40, SD = 0.96). The distribution of men (n = 6, 4.7%) and women (n = 3, 4.2%) was similarly among those participants above the cut-off for clinically relevant burnout symptoms, $\chi^2(1) = 0.03$, p = ns.

The inter-item correlations exceeded the critical value of 0.20, and all item-total correlations were above the threshold of 0.40, for each of the three SMB*M* subscales. The Cronbach's alpha values were satisfactory across all SMBM indices (physical exhaustion = 0.92, cognitive weariness = 0.95, emotional exhaustion = 0.90, SMBM overall index = 0.95).

With respect to convergent validity (**Table 2**), we observed positive associations between the SMB*M* (subscales and overall index), self-perceived stress (r = 0.42–0.59), the ERI ratio (r = 0.14–0.31), and the JDC ratio (r = 0.12–0.32). Only a statistically nonsignificant trend towards a positive relationship was found between emotional exhaustion and the ERI/JDC ratios. Finally, overall mental distress was positively associated with all SMBM indices (r = 0.43–0.62, $p < 0.001$).

A good model fit was found for the three-factor CFA model. Moreover, both the first- and second-order model were supported (**Table 3**). Evidence for weak measurement invariance (invariant factor loadings) across genders was supported. As shown in **Figure 1**, very good factor loadings were observed across all items (all loadings ≥ 0.63), both for women and men. With regard to the first-order model, the three SMB*M* subscales were strongly correlated with each other (r = 0.55–0.63, $p < 0.001$).

DISCUSSION

The present studies show that the German version of the SMB*M* has adequate psychometric properties and acceptable convergent validity and can therefore be used in burnout research in various samples of adult workers. Moreover, the factor structure of the SMB*M* was supported in CFA and found to be gender invariant. This work expands the current literature in an important way in that we, for the first time, thoroughly examined the validity of the SMBM among adult workers and examined whether the instrument performs equally well in male and female participants. Given that the SMBM is among the most widely used instruments to assess burnout symptoms, such an analysis seemed highly warranted. Based on the study aims, four hypotheses were formulated; below, each hypothesis is discussed in detail.

With the first hypothesis we expected that, compared to male participants, female participants would report higher burnout symptoms, and data from police officers confirmed this. However, contrary to our hypothesis, no gender differences were found in the broader sample of adult workers, which is at odds with prior research in adult populations (50, 57). How to explain this unexpected pattern of results? While in our adult sample, no gender difference existed with regard to age, BMI, marital status, children at home, caregiving, job experience, educational level, smoking status, and use of medication, we found that men had a higher mean employment rate than women (96.2% vs. 78.84% in full-time employment). Therefore, it can be speculated that the lack of gender differences might be attributed to lower employment rates among women. However, a higher full-time employment rate was also found among male (90%) compared to female (56%) participants in our sample of police officers. An alternative explanation might be that burnout levels were generally low in the sample of adult workers, with only 5.8% reporting clinically relevant burnout symptoms (46). However, we acknowledge that generally low burnout levels were also observed in our sample of police officers. With regard to the low burnout levels, we argue that the recruitment strategies to address adult workers and police officers might have led to a selection bias in the sense that students more often contacted healthy people, and/or that healthy people were more willing to participate in the study. Finally, in line with previous studies (24, 57), higher subscale mean scores were found for physical fatigue in both samples and genders if compared to cognitive weariness and emotional exhaustion.

With the second hypothesis, we expected that internal consistency of the SMB*M* would be satisfactory in both adult workers and police officers and both women and men (23, 24, 32), and generally, our data confirmed this. Thus, all Cronbach's alpha coefficients exceeded ≥0.70, for all SMB*M* indices, in both male and female participants, and across both samples. Moreover, we found inter-item correlations of ≥0.20 within the respective factor for both male and female participants. All item-total correlations exceeded the critical value of 0.40. Finally, according to the standards recommended by West et al. (74), we observed that the descriptive statistics met the prerequisites for parametric tests, with skewness being <2 and kurtosis being <7 across all SMB*M* indices.

With the third hypothesis we expected to find evidence for the convergent validity of the SMB*M* in both male and female participants. Full support was found for this hypothesis. In accordance with previous studies (52, 50, 55), the SMB*M* overall index was at least moderately and positively associated with participants' levels of perceived stress. In our two populations, we also found weak-to-moderate (positive) correlations between the SMB*M* indices and occupational stress, which accords well with previous research in this area (75–77). The observation that stronger correlations were found for the PSS can be explained by the fact that the PSS is a general measure of stress, whereas the ERI and JDC ratios assess specific forms of occupational stress that might not be applicable for some participants. Moreover, our results corroborate prior research, in which at least moderate correlations were observed between the SMB*M* overall index and mental health outcomes such as depressive symptoms (44, 45, 48). The correlations were moderate-to-strong in both populations, with slightly higher correlations found in police officers. However, these differences are difficult to interpret because we used different instruments to assess mental health in each sample. In the adult worker sample, our findings suggest that the SMB*M* overall index and depressive symptoms have 26.0% (women) and 30.3% (men) of common variance. As highlighted by Melamed et al. (27), it can be expected that burnout and depressive symptoms have a certain overlap because they share some characteristic features such as fatigue and loss of energy.

Support was also found for our fourth and final hypothesis, that the three-factorial model would fit well with the empirical data: The findings of our studies indicate that a three-factor model provided an excellent model fit across all samples, with all factor loadings being strongly linked to the respective factors (24). The first-order model showed that the latent factors were moderately to highly correlated with each other (r = 0.51–0.76, $p < 0.001$) [cp. Refs, (19, 23, 57)]. Following Shirom and Melamed (19), this magnitude of correlations between the SMB*M* subscales is to be expected because every individual possesses a pool of energetic resources. These resources are closely interrelated, and a deficit in one resource can lead to deficits in other resources. Moreover, in line with a previous study with Canadian workers (24), our findings support the factorial validity of a second-order model. This lends further support to the notion that it is legitimate to use the SMB*M* overall score as a global/general burnout index. Sassi and Neveu (24) found that overall burnout explained 63, 53, and 27% of variance in physical exhaustion, cognitive weariness, and emotional exhaustion, respectively, which was comparable to the findings reported in our analyses (physical exhaustion, 56–64%; cognitive weariness, 62–79%; emotional exhaustion, 33–50%). The fact that an adequate model fit was found for the second-order model indicates that the items of the SMB*M* subscales can be aggregated to form an overall burnout index. Finally, for the first time, our results provide evidence for weak-to-strict measurement invariance across male and female workers. This is an important finding because Widaman et al. (69) argued that, if participants' answers vary so much as a function of gender that significant differences emerge in the factor structure of that instrument, the measuring device must change. The same would be the case for relevant ceiling or floor effects occurring for male and female participants. Thus, the present analyses suggest that the SMB*M* is equally suitable to assess burnout symptoms independent of participants' gender.

Despite the novelty of our study, some methodological shortcomings should be mentioned that might limit the generalizability of our data: First, the cross-sectional nature of our studies did not allow us to examine test–retest reliability and predictive validity. Second, the correlations reported in the present samples were not controlled for other demographic factors, although previous studies have shown that participants with elevated burnout are more often divorced, blue-collar workers, have lower education levels, are foreigners, unemployed, financially strained, use more medication, and report less healthy behaviors (50, 52, 54). Third, both samples consisted of nonclinical populations. Therefore, it was not possible to examine the discriminant validity of the SMB*M*, particularly as the number of participants with clinically relevant burnout levels was low in the present study. Accordingly, we were unable to test the discriminant validity of the cut-off for clinically relevant burnout (≥4.40), which Lundgren-Nilsson et al. (20) previously suggested for the SMBQ. This is an important shortcoming that should be addressed in future research. Fourth, while for study 1, we attempted to recruit a sample of adult workers that is broad in terms of employment, education, age, and gender, we did not assess specific information about the participants' occupations. Thus, we were not able to examine whether the described relationships differ according to varying professions. Finally, we acknowledge that there are other validated instruments to assess burnout symptoms in German-speaking (and international) populations. One such instrument is the Oldenburg Burnout Inventory (OLBI) (78–80), in which burnout symptoms are operationalized via two dimensions (exhaustion, disengagement from work). As it applies for the SMBM (14 items, based on COR theory), it is a particular strength of the OLBI that the instrument is concise (16 items) and that it has been developed based on a solid theoretical foundation (Job Demands–Resources model of burnout). We therefore suggest that this instrument could be used in future research to test the discriminant validity of the SMB*M*. Specifically, we would expect that the SMB*M* scales are more strongly correlated with the exhaustion than the disengagement from work subscale of the OLBI. A strong correlation can be expected with the exhaustion subscale because, as in the SMB*M*, the OLBI assesses affective, cognitive, and physical aspects of exhaustion.

CONCLUSIONS AND PRACTICAL RELEVANCE

The SMB*M* is among the most widely used tools in international burnout research. Our study shows, for the first time, that the German version of the instrument has adequate psychometric properties and satisfactory convergent and factorial validity in a broad sample of adult workers and police officers. The SMB*M* can provide relevant information for screening and treatment planning. More research is needed to establish the validity of the cut-off score for clinically relevant burnout. This is essential for finding out whether the SMB*M* can be used in the early screening process to identify employees who might suffer from clinically significant burnout symptoms.

DATA AVAILABILITY

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request *via* the Ethics Committee of Northwestern and Central Switzerland (EKNZ), Ms. Nienke Jones (Nienke.jones@bs.ch; +41 61 268 13 54). At the time of obtaining ethical clearance for the present study from the EKNZ, and in line with Swiss laws, we stated that only authorized researchers who are directly involved in the present project will have access to the raw data. Accordingly, and in line with this statement, we cannot grant access to the data for third parties, unless this is officially approved by the EKNZ.

ETHICS STATEMENT

All procedures were in line with the ethical principles described in the Helsinki Declaration. The data collection and treatment of the participants is in line with the APA ethical standards. The Ethics Committee for Northwest/Central Switzerland (Ethikkommission Nordwest- und Zentralschweiz) approved the studies of both samples. Sample 1: Written informed consent was obtained from all participants prior to data assessment (study approval number: EKNZ: 240/12). Sample 2: All participants provided written informed consent prior to data assessment (study approval number: EKNZ: Project-ID: 2017-01477).

AUTHOR CONTRIBUTIONS

RS, SB, and MG made substantial contributions to conception and design of the study. SL and RS were responsible for the acquisition of data. RS, FC, and MG were responsible for the analysis and interpretation of data. RS and MG drafted the manuscript. FC and SB wrote sections of the manuscript. SB, SL, and FC critically reviewed and revised the initial draft. All authors have approved the final version of the submitted manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2019.00536/full#supplementary-material

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

3.3 Publication 3: Cross-sectional analysis on stress-buffering effects of cardiorespiratory fitness on cardiovascular and mental health

Title:

Does Cardiorespiratory Fitness Moderate the Association between Occupational Stress, Cardiovascular Risk, and Mental Health in Police Officers?

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Published in:

International Journal of Environmental Research and Public Health, 2019, 16(13).

Publication available at:

https://www.mdpi.com/1660-4601/16/13/2349

International Journal of
Environmental Research and Public Health

MDPI

Article

Does Cardiorespiratory Fitness Moderate the Association between Occupational Stress, Cardiovascular Risk, and Mental Health in Police Officers?

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Received: 28 May 2019; Accepted: 29 June 2019; Published: 3 July 2019

Abstract: *Background:* Chronic exposure to occupational stress may lead to negative health consequences. Creating less stressful work environments and making employees physically and psychologically more resilient against stress are therefore two major public health concerns. This study examined whether cardiorespiratory fitness moderated the association between occupational stress, cardiovascular risk, and mental health. *Methods:* Stress was assessed via the Effort-Reward Imbalance and Job Demand-Control models in 201 police officers (36% women, Mage = 38.6 years). Higher levels of blood pressure, blood lipids, blood sugar, and unfavorable body composition were considered as cardiovascular risk factors. Burnout, insomnia and overall psychological distress were used as mental health indicators. Cardiorespiratory fitness was assessed with a submaximal bicycle test. *Results:* High cardiorespiratory fitness levels were associated with a reduced cardiometabolic risk, whereas high stress levels were associated with better mental health. Among participants who perceived a high Effort-Reward Imbalance, those with high fitness levels showed lower overall cardiovascular risk scores than their colleagues with low fitness levels. *Conclusions:* Work health programs for police officers should consider the early screening of burnout, sleep disturbances, and overall mental wellbeing. To increase cardiovascular health, including fitness tests in routine health checks and promoting physical activity to further increase cardiorespiratory fitness appears worthwhile.

Keywords: cardiorespiratory fitness; cardiovascular health; psychosocial stress; police officers; mental health

1. Introduction

Prolonged exposure to stressful life circumstances that exceed individuals' coping capacities can result in emotional, cognitive, physiological and somatic health impairments [1]. While most individuals are able to handle short-term stress, chronic stress can have severe health consequences [2]. Studies show that high levels of psychosocial stress are a risk factor for cardiovascular diseases (CVDs), with an impact comparable to smoking or diabetes, and that a dose-response relationship exists between psychosocial stress and premature death [3,4].

Adverse work conditions constitute a major source of distress for many adults [5]. Despite multiple efforts during the past decade, work-related stress has not substantially decreased in European countries [6]. Accordingly, costs associated with occupational stress (e.g., due to health care, absenteeism, presenteeism, reduced productivity, increased turnover) remain high, and can be estimated at 0.5 to 1.2% of the gross domestic product (GDP) [7].

In the occupational stress literature, two of the most prominent theoretical models are the job demands-control (JDC) model [8] and the effort-reward imbalance (ERI) model [9]. Broadly speaking, the JDC model assumes that stress occurs when workers perceive a discrepancy between the demands they face at work and their ability to control those requirements with their existing resources. In the JDC model, such an imbalance is labelled as "job strain". By contrast, the ERI model assumes that employees perceive their work as stressful, if they have the feeling that they invest a lot of energy (efforts), but do not get enough recognition (reward) for their efforts. Empirical evidence supports the validity of both models showing that an imbalance between demands/control and efforts/reward is associated with an increased risk for impaired mental wellbeing (e.g., burnout, anxiety, impaired sleep quality), decreased physical health (e.g., coronary heart disease, musculoskeletal disease), and premature death [10,11].

According to the World Health Organization [12], CVDs are the leading cause of deaths worldwide. In their review of prospective epidemiologic studies, Siegrist and Dragano [11] highlighted that high job strain doubles the risk for CVDs, particularly among men. Similarly, Nyberg et al. [13] found in a meta-analytic survey that work-related stress was linked to an increased risk for CVDs, mainly due to an elevated risk for type II diabetes, smoking, and physical inactivity. In line with this notion, the American Heart Association provided recommendations on the most relevant factors to maintain cardiovascular health [14]. These include: body mass index <25; ≥ 30 min of moderate intensity physical activity per day; <200 mg/dL of total blood cholesterol; $\leq 120/80$ mmHg blood pressure; and ≤ 100 mg/dL fasting blood glucose [14]. As highlighted by Mottillo et al. [15], if individuals fail to meet several of these recommendations, their risk of all-cause mortality substantially increases.

Additionally, ample evidence exists for a close link between occupational stress and decreased mental wellbeing [16]. In high-income countries, the social burden of mental disorders is high, with costs estimated at 2.3 to 4.4% of the GDP [17]. Based on their review of prospective epidemiologic studies, Siegrist and Dragano [11] concluded that high occupational stress (as measured via a JDC or ERI imbalance) is associated with a 1.2 to 4.6-fold increased risk for depression. Additionally, occupational stress has been described to be the most important cause of burnout among adult workers [18], and seems to be closely associated with sleep complaints [19].

In the present study, we specifically focused on the occupation of law enforcement. Policing has often been described as a particularly (emotionally) stressful occupation [20,21]. In their professional lives, police officers have to deal with death, suffering, poverty, and physical threats; consequently, they are frequently required to draw on their physical and mental resources [22]. As emphasized by Waters et al. [23], some police officers start their career healthy, but develop severe health issues if the cumulative impact of stress becomes too big and takes its toll. Habersaat et al. [24] point out that police officers are a heterogeneous population, and that their health risk seems to depend more on individual perceptions of their work conditions than on characteristics of the division-specific work environment. This is in line with study findings reported by Gerber et al. [20], who observed that officers' mental health is more closely related to their subjective stress perception than their shift work status, a factor associated with ill-health in other studies [25]. While ample evidence exists showing that chronic stress exposure contributes to both mental [26] and physical health issues [27,28], research is equivocal regarding the question of whether police officers are more at-risk for impaired health than other professions. For instance, previous research has shown that in the United States, many police officers have below-average fitness levels [29], and are more likely to be obese, to suffer from metabolic syndrome and to have higher total cholesterol levels than the general population [30]. By contrast, van der Velden et al. [31] reported that although policing is generally considered as a high-risk profession, no evidence exists to suggest that Dutch police officers are more likely to develop mental health disturbances than employees of banks, supermarkets, and psychiatric hospitals.

Given the negative health consequences associated with chronic occupational stress in both police officers and other professions [10,32], creating less stressful work environments and finding ways to make employees more resilient against stress are two major public health concerns [33,34]. Since the early 1980s, researchers have discussed whether participation in regular physical activity or having sufficiently high fitness levels might protect employees from the health hazards associated with chronic occupational stress [35]. While such "stress-buffering" effects of physical activity and physical fitness are supported in the literature [36], few studies have focussed on occupational stress. Among the existing studies, researchers often failed to use theory-based instruments to assess stress [37,38], focussed on physical demands at work instead of psychological strain [39], and relied on self-reports (instead of objective measures) to assess physical activity or physical fitness [40–43]. While the existing studies generally support the notion of physical activity/fitness as a stress-buffer, it must also be noted that few studies used objective measures to assess health. Nevertheless, in a 30-year follow-up study, Holtermann et al. [39] found that participants with high work demands had a higher risk of ischaemic heart disease and all-cause mortality, if compared to participants with low physical work demands. However, this only applied to men with low fitness levels, whereas no such relationship was found among men with high fitness. Similarly, Gerber et al. [37] reported that employees with high scores on a simple 1-item stress questionnaire had a higher total metabolic risk as compared to counterparts with lower stress levels. Again, this relationship was only observed among employees with low fitness levels, whereas no association between occupational stress and cardiometabolic risk occurred among employees with moderate or high fitness levels. Finally, Schmidt et al. [44] reported that employees with high scores on a maximal fitness test were less likely to be affected by high job-related self-control demands.

Given this background, the purpose of the present study was to find out whether cardiorespiratory fitness levels moderated the relationship between occupational stress, cardiovascular and mental health outcomes. The present study goes beyond existing research in several ways: First, we used the two most established models (JDC/ERI) to assess occupational stress. Second, contrary to previous studies, in which researchers often used self-reported physical activity as an easily measurable proxy for physical fitness, we used an established submaximal fitness test to estimate participants' maximal oxygen uptake. Third, contrary to most previous studies, we included objective physical health markers in order to find out whether the stress-buffering effects of physical fitness could be generalized beyond subjective health complaints and symptoms of mental ill-health.

Based on the literature presented above, we formulated three hypotheses:

- Our first hypothesis was that higher levels of occupational stress will be associated with an increased cardiovascular risk, and more frequent mental health complaints, independent of the model used to operationalize occupational stress.
- Our second hypothesis was that higher levels of cardiorespiratory fitness will be associated with a lower cardiovascular risk, and fewer mental health complaints.
- Our third hypothesis was that cardiorespiratory fitness will moderate the relationship between occupational stress and physical/mental health indicators: Thus, the relationship will become smaller as a function of increasing fitness levels, independent on whether occupational stress is operationalized via the JDC or ERI model.

2. Materials and Methods

2.1. Participants and Procedures

Participants were recruited from a police force in Basel, a bigger city in the northwestern, German-speaking part of Switzerland. All officers (N = 980, 290 females, 690 males) were invited to participate in the study, consisting of a comprehensive health check, including a cardiorespiratory fitness test, 7-day actigraphy, anthropometry, blood pressure assessment, a computerised cognitive test (facial emotion recognition), a functional movement screen, a lung function test, and an online-survey focusing on stress and mental health. Different channels were used to advertise the study including emails via intranet, video clips on the internal TV channel, printed flyers, and oral information during team meetings. For interested officers, more specific information (e.g., regarding the voluntary nature of participation, no negative consequences in case of non-participation, information about benefits and risk, information about measurements) was provided via short text modules and video messages via an e-learning tool. Data assessment took place between October 2017 and March 2018. As an incentive, each participant received a personalized health profile after the completion of the data assessment. Moreover, participants had the possibility to take part in a voluntary lifestyle coaching program.

No specific inclusion and exclusion criteria were applied. However, to be allowed to take part in the cardiorespiratory fitness test, participants were asked to sign the written informed consent and fill in an extended version of the Physical Activity Readiness Questionnaire (PAR-Q) [45]. Thus, workers were not allowed to perform the cardiorespiratory fitness test, if they reported any conditions that prevent participation in a submaximal fitness test, as defined by the American College of Sports Medicine (ACSM) [45]. In case of uncertainty, participants were asked to consult a general practitioner (and provide a doctor's certificate). Furthermore, participants were only allowed to perform the cardiorespiratory fitness test if they did not report a temporary illness such as a cold or a fewer. If participants were not able/allowed to take part in the cardiorespiratory fitness test, they still could perform all other tests.

The data assessment took place during official working hours. The 120-min laboratory testing was carried out at the education and training center of the police force, and all tests were performed in a private setting in a specific room reserved across the entire study period by the same investigator.

The regional ethical review board (EKNZ: Project-ID: 2017-01477) approved the study, which was performed in accordance with the ethical principles laid down in the current edition of the Deceleration of Helsinki.

2.2. Measures

2.2.1. Occupational Stress

Two different scales were used to assess work-related stress, referring to the two most widely used job-related stress theories [46], the Job Demand and Control (JDC) [47] and the Effort-Reward Imbalance (ERI) model [48]. The demand scale from the JDC model contains five items on a 4-point Likert-scale ranging from 1 (never) to 4 (often). For example, participants were asked whether their job requires them to work very fast, hard, or to accomplish large amounts of work. Participants also completed six items on the subscale pertaining to control (e.g., 'I have freedom to make decisions about my job'). The items were summed to obtain subscale scores for job demand and job control. Because of the unequal number of items the JDC-ratio was calculated with the following formula: job demand/(job control × 0.8333). Values >1 of the JDC-ratio indicated stress with possible adverse health effects [49]. The validity and reliability of this instrument has been established previously [50]. The effort scale of the ERI model consists of five items anchored on a 5-point Likert-scale from 1 (none) to 5 (very high). Sample items were: 'I have a lot of responsibility in my job' or 'I have many interruptions and disturbances in my job.' The reward scale consists of 11 items with the same semantic anchors (e.g., 'I receive the respect I deserve from my superior or a respective relevant person.' or 'Considering all my efforts and achievements, my job promotion prospects are adequate.'). The ERI-ratio was calculated with the following formula: effort/(reward × 0.4545). This measure has previously proven to be valid and reliable [51]. ERI-ratio scores above 1 reflect higher levels of job stress [48].

2.2.2. Cardiovascular Risk Markers

Blood pressure, height, weight, waist circumference, body composition, blood lipids and blood glucose were assessed as cardiovascular risk markers. Blood pressure was measured with a portable device (OMRON M500, OMRON Healthcare Co. Ltd. 53, Kunotsubo, Terado-cho, Muko, Kyoto 617-0002 Japan), which was attached to the left arm. Two measurements were taken with approximately one minute's break in between. The mean of the two measurements was used for further analyses [52]. Systolic and diastolic blood pressure were used as outcome measures. Height was measured to the nearest five mm using a stationary stadiometer. Weight and body composition were assessed with a wireless body composition monitor (BC-500, Tanita Corp., Tokyo, Japan). The participants were asked to fast three hours before the data assessment, to not take part in exhausting sport activities 24 h prior to the testing, to void their bladder prior to the data assessment, and to wear only light sport clothing (≤1 kg). The instrument assessed the participants' weight to the nearest ten g, which was corrected for clothes (minus one kg). The Body Mass Index (BMI) was calculated (weight (kg) * height (m)$^{-2}$) as an outcome variable. Moreover, body fat was assessed as an outcome variable. Blood lipids and blood glucose were assessed via finger prick, and instantly analyzed using the Alere Afinion AS100 Analyzer (Abbott Diagnostics, Alere Technologies, Rodeløkka NO-0504 Oslo, Norway). Alere lipid and glucose panel controls were used to ensure the reliability of the analyzers. Two drops of blood were needed to assess blood glucose (HbA1c), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and triglycerides (TG). Capillary blood sampling is a frequently used minimal invasive and minimal painful method, and is regarded as being quicker and less distressing than venipuncture [53]. The finger prick was performed following the standardization protocol of the World Health Organization (WHO) [53], in order to maintain good clinical utility and high accuracy [52,54]. The validity and reliability of the applied instruments and procedures have been documented in previous research [55–57].

2.2.3. Mental Health

We used the Shirom–Melamed Burnout Measure (SMBM) to assess occupational burnout symptoms [58]. The SMBM is a validated and widely used tool that comprises 14 items with response options on a 7-point Likert scale from one (almost never), to seven (almost always). The items can be assigned to three dimensions: six items refer to the aspects of physical fatigue, five items to cognitive weariness, and three items refer to emotional exhaustion. The mean score is built to obtain an overall burnout index, with values of ≥4.40 being considered as clinically relevant [59]. Subjective sleep complaints were assessed with the brief 7-item self-report Insomnia Severity Index (ISI) [60]. Referring to the last month, participants state their difficulties falling asleep, difficulties maintaining sleep, early morning awakenings, daytime fatigue, daytime performance, satisfaction with sleep, and worrying about sleep. Answers were given on a 5-point Likert scale, scored from 0 (e.g., no problem at all) to 4 (e.g., very severe problem), yielding a total of 0 to 28, with higher scores being indicative of more frequent sleep complaints. Scores should be interpreted as follows: 0–7 = absence of insomnia; 8–14 = sub-threshold insomnia; 15–21 = moderate insomnia; 22–28 = severe insomnia [61]. Adequate measurement properties have been shown previously [62]. The German version of the General Health Questionnaire (GHQ-12) was used to assess mental distress or minor psychiatric morbidities [61,63]. The GHQ-12 has been frequently used in the literature and its validity and reliability have been extensively reviewed [63]. Participants self-report their mental well-being during the previous week. Answers can be given on a 4-point Likert scale ranging with response options being 0 (not at all), 1 (same as usual), 2 (more than usual), and 3 (much more than usual). Sum scores range from 0 to 36, with higher scores reflecting higher levels of mental distress. Currently, no standard cut-off values exist for dividing up "cases" identified by a GHQ-12 score threshold. However, researchers have used the following categories to successfully establish links between the GHQ-12 and mortality (if response options 0 + 1 = 0, and 2 + 3 = 1): asymptomatic (0), subclinically symptomatic (1–3), symptomatic (4–6), highly symptomatic (7–12) [4,64]. In the present sample, internal consistency was acceptable across all mental health indicators. Cronbach's alphas were 0.94 for burnout symptoms, 0.74 for sleep complaints, and 0.87 for mental distress.

2.2.4. Cardiorespiratory Fitness

Cardiorespiratory fitness was tested with the Åstrand Fitness Test, a submaximal test performed on a bicycle ergometer [65]. Based on participants' heart rate, maximal oxygen consumption (VO_{2max}), which is a measure of cardiorespiratory fitness, was estimated indirectly [66]. Participants were instructed to avoid any strenuous activity for 24 h prior to the testing, as well as heavy meals, caffeine, or nicotine for three hours before the testing. Before starting the test, participants were equipped with a heart rate monitor. For men, the test protocol was standardized at a workload of 150 watts, for women at 100 watts. The workload was adjusted so that the heart rate is kept between 130 beats per minute (bpm) and 160 bpm, and between 120 bpm and 150 bpm in participants from the age of 40. The subjects were asked to cycle at a pace of 60 rotations per minute (rpm) for six minutes. At the end of each minute, the subject's heart rate was noted. After two minutes, the participant reached a steady state, where only minor heart rate fluctuations occurred within the target heart rate zone. During the test, standardized encouragements were used and cancellation criteria were monitored. After six minutes, the test ended. Using a nomogram, the mean heart rate of minute five and six are compared against the watts that the participant trained at. Depending on the subject's age, a correction factor was applied, and the VO_{2max} per kg was determined [67]. Gender and age-adjusted norms were used to classify participants in groups with low, moderate or high fitness levels [68].

2.3. Statistical Analyses

A power analysis (using G*Power 3.1.9.3, Heinrich Heine University, Dusseldorf, Germany) indicated that for F-tests (ANCOVA: Fixed effects, main effects and interactions) a minimum of 158 participants are needed to detect moderate effects (alpha error = 0.05, power = 0.80, df = 2, groups = 3).

Descriptive and inferential statistics were calculated using IBM SPSS Statistics 25 (IBM, Armonk, NY, USA). We carried out two separate two-factorial multivariate analyses of covariance (MANCOVAs) with (a) cardiovascular risk factors and (b) mental health outcomes as dependent variables, which were followed by a series of two-factorial analyses of covariance (ANCOVAs) to examine main and interaction effects of stress and CRF levels. To ensure a sufficient number of participants per cell, we compared two groups with low vs. high stress levels, and three groups with low, moderate, and high fitness levels. All analyses were controlled for age, gender, education ("What is your highest level of education; without the police training?"), employment rate ("What was your average employment level over the last 6 months?"), relationship status ("What is your current relationship situation?" Response options: single; married or in a relationship), children at home ("How many children do you have who still live at home?"), caregiving responsibility ("Are you currently the main person responsible for a family member or friend in need of care?"), supervisor status ("How many people do you have direct supervision responsibility for?"), work experience ("How many years have you been employed by the police?"), shift-work status ("Do you work in shifts or daytime?"), smoking ("Do you smoke?"), and medication intake ("Do you regularly take medication?"). To maximize statistical power, all outcomes were treated as continuous variables in the (M)ANCOVAs (and not as risk categories) [45]. Moreover, all missing values were replaced via expectation maximation (EM) algorithm [69]. The 5% level of significance was used to test main and interaction effects. Partial eta squared (η^2) were used to interpret the strengths of the effects. Beyond single cardiometabolic risk factors, we also calculated a clustered metabolic risk index, which corresponded to a continuously distributed score (with higher scores being indicative of higher total cardiometabolic risk). To obtain this score, the z-standardized residuals were computed for the following variables [45]: (SBP/DBP)/2, BMI, waist circumference, body fat, TC, HDL-C (*−1), LDL-C, TG and Hb1Ac.

3. Results

3.1. Sample Description

Two hundred and one (201) officers (129 men, 72 women) volunteered to take part in the data assessment. The mean age was 38.6 years (standard deviation [SD] = 10.1). Twenty percent reported living alone, whereas 80% were married or living with someone. On average, officers were working since 12.9 years (SD = 8.8) in the police force (range: 1–37 years). Most of the participants were full-time employees (83%), 12% reported employment rates between 50 and 90%, and 6% reported an employment rate between 20 and 40%. Fourteen percent of the participants have higher education (college/university degree), 32% have completed high school or advanced vocational training, whereas 54% have basic vocational training. More than half of the participants (57%) had no children, whereas 16% had one child, 24% two children, and 3% three or more children. Three percent currently had carer responsibilities, 47% percent of the participants were shift-workers, 20% were smokers, and 16% reported that they take medication on a regular basis. Finally, 37% had supervisor status, with supervisors being responsible for 1 to 80 subordinate employees (M = 10.7, SD = 14.8).

3.2. Descriptive Statistics and Correlations between Independent and Dependent Variables

Descriptive statistics for all independent and dependent variables are summarized in Table 1. Following Cifkova et al. [70], 17.9% and 32.2%, of the participants were classified as hypertensive based, respectively, on the cut-off for systolic (≥140 mmHg) and diastolic blood pressure (≥90 mmHg). Based on WHO [71] recommendations, 52.2% of the participants were classified as overweight (BMI ≥ 25.0 kg/m^2), and 9.5% as obese (BMI ≥ 30.0 kg/m^2). Following the expert panel of the National Cholesterol Education Program [72], which defined a waist circumference of ≥80 cm (women) and ≥94 cm (men) as risk factor for metabolic syndrome, 65.3% of women and 45.7% of men exceeded this cut-off. With regard to body fat, the WHO [71] recommends maximum levels of ≥32% for women and ≥25% for men. Based on these standards, 22.2% of women and 11.1% of men had excessive body fat levels. Following Rodondi et al. [73], the following clinically relevant cut-offs should be considered for total cholesterol (≥5.6 mmol/L), HDL-C (≤1.41 mmol/L) and LDL-C (≥3.40 mmol/L). In the present sample, these cut-offs were exceeded by 25.9% (total cholesterol), 16.4% (HDL-C) and 10.9% (LDL-C) of the participants. Moreover, based on the recommendations of the expert panel of the National Cholesterol Education Program [72], 31.3% exceeded the clinical cut-off for triglycerides (≥1.71 mmol/L). Following the criteria of the American Diabetes Association [74], we identified 31 participants with prediabetes (HbA1c ≥ 5.7%) and three participants with diabetes (HbA1c ≥ 6.5%).

With regard to mental health, burnout scores of ≥4.40 can be considered as clinically relevant [59], whereas scores of ≥15 [61] and 4 [75], respectively, point towards clinical levels of insomnia or excessive mental distress. Based on these standards, 4.0%, 6.5% and 14.4% reported clinically relevant levels of burnout, sleep complaints, and excessive mental distress.

Two of the variables (triglycerides, HbA1c) exceeded the recommended values for skewness (value of 2) and kurtosis (value of 7) [76]. We therefore built the logarithm of these scores before calculating the ANCOVAs.

With regard to stress, 80 participants (40%) had JDC scores >1 and 54 participants (27%) had ERI scores >1. These participants were considered as being exposed to high occupational stress levels. Finally, based on the ACSM classification standards, 53 participants (26%) had low CRF, 59 participants (29%) had moderate CRF, and 89 participants (44%) had high CRF levels.

Bivariate correlations between independent and dependent study variables are displayed in Table 1. Significant correlations were found between both occupational stress measures and the three mental health indicators. Few significant correlations existed between the JDC and ERI ratio and the cardiovascular health outcomes. The only significant correlations were found between the JDC ratio and HbA1c, and the ERI ratio and BMI, waist circumference, as well as the total cardiometabolic risk factor score. Higher CRF was correlated with higher BMI, higher waist circumference, lower body fat, and lower HDL cholesterol. By contrast, no significant correlations were found between participants' CRF level and any of the mental health indicators. Weak to moderate correlations existed between most of the various cardiometabolic risk factors, whereas moderate to strong correlations were observed between burnout symptoms, insomnia symptoms and overall mental wellbeing.

Table 1. Descriptive statistics for and bivariate correlations between independent and dependent variables.

Descriptive Statistics	*n*	M	SD	Range	Skew	Kurt	Bivariate Correlations between Independent and Dependent Variables															
							1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Stress																						
1. JDC ratio	201	1.0	0.2	0.5 to 1.6	0.7	0.4	-															
2. ERI ratio	201	0.9	0.3	0.3 to 2.0	0.9	1.5	0.33 *	-														
Cardiorespiratory fitness																						
3. VO_{2max}	201	3.5	0.9	1.6 to 5.9	0.3	−0.6	0.10	0.05	-													
Cardiovascular risk factors																						
4. SBP (mmHg)	201	129	13	104 to 172	0.5	0.2	−0.05	0.13	0.10	-												
5. DBP (mmHg)	201	85	10	63 to 118	0.2	−0.3	−0.11	0.12	0.02	0.84 *	-											
6. BMI ($kg \cdot m^{-2}$)	201	25.8	3.6	17.9 to 37.4	0.7	0.8	0.00	0.16 *	0.25 *	0.33 *	0.37 *	-										
7. Waist circumference (cm)	201	91.1	11.3	60.0 to 126.0	0.4	0.8	−0.08	0.14 *	0.20 *	0.37 *	0.43 *	0.83 *	-									
8. Body fat (%)	201	21.8	7.3	5.6 to 42.6	0.4	−0.2	−0.01	0.02	−0.38 *	0.01	0.03	0.37 *	0.30 *	-								
9. TC ($mmol \cdot L^{-1}$)	201	5.0	1.0	2.9 to 10.4	1.1	3.2	−0.11	0.05	0.00	0.28 *	0.34 *	0.31 *	0.32 *	0.14	-							
10. HDL-C ($mmol \cdot L^{-1}$)	201	1.8	0.4	0.6 to 2.6	0.1	−0.5	−0.07	−0.08	−0.14 *	−0.13	−0.15 *	−0.35 *	−0.35 *	0.15 *	0.20 *	-						
11. LDL-C ($mmol \cdot L^{-1}$)	201	2.5	0.8	1.0 to 5.0	0.6	0.2	−0.06	0.05	0.05	0.24 *	0.33 *	0.28 *	0.29 *	0.05	0.81 *	−0.06	-					
12. TG ($mmol \cdot L^{-1}$)	201	1.7	1.2	0.5 to 7.4	2.3 (0.6)	6.5 (0.2)	−0.07	0.09	0.03	0.26 *	0.27 *	0.42 *	0.41 *	0.05	0.53 *	−0.29 *	0.12	-				
13. HbA1c (%)	201	5.4	0.3	4.9 to 7.5	2.4 (1.7)	13.7 (6.9)	−0.15 *	0.03	−0.06	0.19 *	0.26 *	0.27 *	0.35 *	0.09	0.09	−0.24 *	0.14 *	0.14	-			
14. Total cardiometabolic risk	201	0.0	4.7	−10.6 to 16.7	0.7	0.8	−0.10	0.15 *	0.06	0.63 *	0.69 *	0.78 *	0.80 *	0.32 *	0.62 *	−0.38 *	0.57 *	0.60 *	0.47 *	-		
Mental health indicators																						
15. Burnout symptoms	201	2.5	1.0	1 to 6	0.9	0.7	0.31 *	0.31 *	−0.08	−0.08	−0.05	0.02	−0.02	0.14 *	−0.08	0.03	−0.09	−0.04	−0.03	−0.05	-	
16. Insomnia symptoms	201	7.9	4.3	0 to 22	0.5	0.0	0.23 *	0.21 *	−0.06	−0.06	−0.05	0.00	−0.02	0.05	−0.01	−0.08	0.00	0.03	−0.04	0.00	0.46 *	-
17. Overall mental wellbeing	201	1.7	2.5	0 to 11	1.7	2.2	0.26 *	0.25 *	−0.04	0.02	0.00	0.14 *	0.09	0.18 *	−0.02	0.08	−0.08	0.02	−0.04	0.04	−0.62 *	0.31 *

Notes: JDC = Job Demands and Control; ERI = Effort Reward Imbalance; VO_{2max} = Maximal Oxygen Uptake; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; BMI = Body Mass Index; TC = Total Cholesterol; HDL-C = High-Density Lipoprotein Cholesterol; LDL-C = Low-Density Lipoprotein Cholesterol; HbA1c = Glycated Hemoglobin; M = Mean; SD = Standard Deviation; Skew = Skewness; Kurt = Kurtosis. Values in brackets for TG and HbA1c for skewness and kurtosis represent values after building the logarithm. * $p < 0.05$.

3.3. Main and Interaction Effects

Job demand and control (JDC model). If stress was operationalized via the JDC model, the MANCOVA showed a significant main effect for the factor CRF, F(20, 350) = 3.2, $p < 0.001$, $\eta^2 = 0.154$, whereas no significant effects occurred for the factor stress, F(10, 175) = 0.4, p = not significant (ns), $\eta^2 = 0.023$, or the interaction between CRF and stress, F(20, 350) = 1.4, p = ns, $\eta^2 = 0.075$, after controlling for covariates. Table 2 further shows the findings of the ANCOVAs, displaying the means and standard deviations for the six subgroups with low vs. high occupational stress, and low, moderate vs. high cardiorespiratory fitness. These values are followed by the inferential statistics (F, η^2 values) for the main effects of stress and cardiovascular fitness, and the interaction between these two constructs. Table 2 yields a relatively consistent picture across all outcomes. Thus, participants with higher fitness levels showed more favorable scores across almost all cardiovascular risk factors (BMI, waist circumference, body fat, HDL cholesterol, triglycerides, HbA1c). No significant main effects for cardiorespiratory fitness were found for systolic and diastolic blood pressure, total cholesterol, and LDL cholesterol. In line with these findings, a relatively strong main effect (12.7% of explained variance) was found for the total cardiometabolic risk index, showing that participants with the highest fitness level had the most favorable scores, followed by those with moderate and low fitness levels (see Table 2).

With regard to the mental health indicators, the MANCOVA yielded a significant main effect for the factor stress, F(3, 182) = 6.8, $p < 0.001$, $\eta^2 = 0.101$, whereas no significant effects were identified for CRF, F(6, 364) = 0.6, p = ns, $\eta^2 = 0.009$, and the interaction between CRF and stress, F(6, 364) = 1.0, p = ns, $\eta^2 = 0.017$. In line with this finding, we found three significant main effects in the univariate ANCOVAs for occupational stress, showing that independent of their fitness levels, officers who perceive higher levels of occupational stress report more symptoms of mental ill-health than their less stressed colleagues. In the univariate analyses, we did not find any significant interaction effects between occupational stress and cardiorespiratory fitness for any of the study variables.

Effort-reward imbalance (ERI model). If stress was operationalized via the ERI model, the MANCOVA showed a significant main effect for the factor CRF, F(20, 350) = 3.2, $p < 0.001$, $\eta^2 = 0.155$, whereas no significant effects occurred for the factor stress, F(10, 175) = 0.9, p = ns, $\eta^2 = 0.047$, or the interaction between CRF and stress, F(20, 350) = 1.1, p = ns, $\eta^2 = 0.062$, after controlling for covariates. As shown in Table 3, the results pattern described for the JDC model was similar when we carried out the univariate ANCOVAs with the ERI model. Again, we found significant main effects for fitness for the following variables: DBP, BMI, waist circumference, body fat, HDL cholesterol, triglycerides, and total cardiometabolic risk. By contrast, no significant main effects were found for occupational stress. Finally, contrary to the results of the multivariate analysis, three significant univariate interactions were observed for total cholesterol, triglycerides, and total cardiometabolic risk. As shown in Figure 1 for the total cardiometabolic risk index, participants with low CRF levels had particularly high cardiometabolic risk scores if exposed to high occupational stress.

As for the JDC model, in the MANCOVA with the mental health indicators as outcomes, we found a significant main effect for stress F(3, 191) = 5.6, $p < 0.001$, $\eta^2 = 0.081$, whereas no significant effects occurred for CRF F(6, 382) = 1.2, p = ns, $\eta^2 = 0.018$, and the interaction between stress and CRF, F(6, 382) = 0.6, p = ns, $\eta^2 = 0.009$, if stress was operationalized via an imbalance between job-related efforts and reward. In line with this, the univariate ANCOVAs indicated significant main effects across all mental health indicators, showing that officers with higher stress levels report more mental health complaints. The effect sizes (4.9 to 10.0% of explained variance) were moderate to strong. No significant interaction effects were found between occupational stress and cardiorespiratory fitness.

Table 2. Differences in cardiometabolic risk factors, and mental health indicators, dependent on participants' levels of CRF and perceived occupational stress (as assessed via the job demand and control [JDC] score).

	Low Occupational Stress (JDC Score)			**High Occupational Stress (JDC Score)**			**Stress (JDC)**		**CRF**		**Stress (JDC) × CRF**	
	Low CRF ($n = 36$)	**Moderate CRF ($n = 34$)**	**High CRF ($n = 51$)**	**Low CRF ($n = 17$)**	**Moderate CRF ($n = 25$)**	**High CRF ($n = 38$)**						
	M ± SD	**M ± SD**	**M ± SD**	**M ± SD**	**M ± SD**	**M ± SD**	**F**	η^2	**F**	η^2	**F**	η^2
Cardiovascular risk factors												
SBP (mmHg)	129 ± 12	130 ± 8	129 ± 15	132 ± 14	132 ± 15	127 ± 13	1.6	0.009	1.2	0.013	3.0	0.032
DBP (mmHg)	88 ± 11	86 ± 7	83 ± 10	86 ± 12	86 ± 10	83 ± 11	0.5	0.002	2.9	0.031	0.7	0.007
BMI ($kg·m^{-2}$)	27.8 ± 4.7	26.3 ± 3.3	24.0 ± 2.7	26.6 ± 4.0	25.8 ± 3.4	25.8 ± 2.6	0.0	0.000	7.1 **	0.071	1.6	0.017
Waist circumference (cm)	97.6 ± 13.6	93.9 ± 10.9	85.6 ± 9.0	95.1 ± 12.3	90.4 ± 9.3	88.6 ± 8.9	0.0	0.000	11.8 ***	0.114	0.9	0.010
Body fat (%)	24.9 ± 7.7	20.8 ± 5.5	20.4 ± 7.3	23.6 ± 6.2	23.4 ± 8.2	19.8 ± 7.0	0.5	0.003	22.1 ***	0.194	1.4	0.015
TC ($mmol·L^{-1}$)	5.1 ± 1.4	5.1 ± 1.1	5.1 ± 0.9	5.3 ± 1.2	4.9 ± 0.8	4.8 ± 0.8	0.2	0.000	0.7	0.007	1.1	0.012
HDL-C ($mmol·L^{-1}$)	1.7 ± 0.4	1.8 ± 0.4	2.0 ± 0.4	1.6 ± 0.5	1.8 ± 0.5	1.9 ± 0.3	0.2	0.001	5.5 **	0.056	0.0	0.000
LDL-C ($mmol·L^{-1}$)	2.5 ± 1.0	2.4 ± 0.8	2.5 ± 0.8	2.6 ± 0.8	2.4 ± 0.7	2.3 ± 0.6	0.0	0.000	0.6	0.007	0.7	0.007
TG ($mmol·L^{-1}$)	1.9 ± 1.3	2.0 ± 1.5	1.4 ± 0.6	2.3 ± 1.9	1.6 ± 1.0	1.4 ± 0.7	0.1	0.001	3.7 *	0.038	1.9	0.020
HbA1c (%)	5.5 ± 0.3	5.5 ± 0.4	5.4 ± 0.2	5.5 ± 0.3	5.5 ± 0.2	5.4 ± 0.2	0.0	0.000	3.6 *	0.038	0.2	0.003
Total cardiometabolic risk	2.8 ± 7.7	0.8 ± 5.0	−2.0 ± 4.9	2.4 ± 6.7	0.3 ± 5.2	−2.0 ± 4.0	0.5	0.003	13.3 ***	0.127	0.2	0.002
Mental health indicators												
Burnout symptoms	2.3 ± 0.9	2.4 ± 1.1	2.4 ± 0.8	2.6 ± 0.9	2.9 ± 1.4	2.9 ± 1.0	15.9 ***	0.080	1.0	0.010	1.8	0.020
Sleep complaints	7.7 ± 4.1	7.2 ± 3.5	6.4 ± 3.6	8.8 ± 4.3	9.4 ± 5.2	9.1 ± 5.0	6.5 *	0.034	0.6	0.007	1.6	0.017
Overall mental distress	1.4 ± 2.0	1.1 ± 2.0	0.9 ± 1.8	1.8 ± 2.1	2.9 ± 3.3	2.5 ± 3.2	14.1 ***	0.071	1.0	0.010	1.2	0.013

Notes: SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; BMI = Body Mass Index; TC = Total Cholesterol; HDL-C = High-Density Lipoprotein Cholesterol; LDL-C = Low-Density Lipoprotein Cholesterol; TG = Triglycerides; HbA1c = Glycated Hemoglobin; JDC = Job Demands and Control; CRF = Cardiorespiratory Fitness; M = Mean; SD = Standard Deviation. All analyses controlled for age, gender, education, employment rate, relationship status, children at home, caregiving responsibility, supervisor status, shift-work status, medication intake. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Table 3. Differences in cardiometabolic risk factors, and mental health indicators, dependent on participants' levels of CRF and perceived occupational stress (as assessed via the effort-reward imbalance [ERI] score).

	Low Occupational Stress (ERI Score)			**High Occupational Stress (ERI Score)**			**Stress (ERI)**		**CRF**		**Stress (ERI) × CRF**	
	Low CRF (*n* = 34)	**Moderate CRF (*n* = 44)**	**High CRF (*n* = 69)**	**Low CRF (*n* = 19)**	**Moderate CRF (*n* = 15)**	**High CRF (*n* = 20)**						
	M ± SD	**M ± SD**	**M ± SD**	**M ± SD**	**M ± SD**	**M ± SD**	**F**	η^2	**F**	η^2	**F**	η^2
Cardiovascular risk factors												
SBP (mmHg)	130 ± 13	130 ± 11	129 ± 15	131 ± 12	132 ± 15	127 ± 13	0.1	0.001	1.9	0.020	1.8	0.019
DBP (mmHg)	87 ± 11	85 ± 8	83 ± 11	87 ± 12	87 ± 10	83 ± 7	0.2	00.001	4.1 *	0.043	1.3	0.014
BMI (kg·m^{-2})	27.0 ± 3.8	25.9 ± 3.4	24.4 ± 2.8	28.1 ± 5.6	26.8 ± 3.0	25.2 ± 2.4	1.7	0.009	9.7 ***	0.095	1.1	0.012
Waist circumference (cm)	95.5 ± 11.8	92.5 ± 10.5	86.2 ± 8.8	99.2 ± 15.3	92.2 ± 10.1	89.3 ± 9.3	0.2	0.001	12.6 ***	0.121	0.4	0.004
Body fat (%)	24.4 ± 8.0	20.0 ± 6.1	20.7 ± 7.0	24.6 ± 6.0	24.4 ± 8.5	18.4 ± 8.2	0.7	0.004	21.2 ***	0.187	0.1	0.002
TC (mmol·L^{-1})	4.9 ± 1.0	5.0 ± 1.0	5.0 ± 0.8	5.6 ± 1.7	5.2 ± 0.9	5.0 ± 0.9	2.4	0.013	1.3	0.014	3.0 *	0.032
HDL-C (mmol·L^{-1})	1.7 ± 0.4	1.7 ± 0.4	1.9 ± 0.4	1.7 ± 0.5	1.9 ± 0.4	1.9 ± 0.4	0.7	0.004	5.5 **	0.057	0.1	0.001
LDL-C (mmol·L^{-1})	2.5 ± 0.9	2.4 ± 0.7	2.4 ± 0.7	2.7 ± 1.0	2.4 ± 0.8	2.5 ± 0.7	0.1	0.000	0.9	0.011	0.8	0.009
TG (mmol·L^{-1})	1.7 ± 0.9	1.7 ± 1.3	1.4 ± 0.6	2.5 ± 2.2	2.0 ± 1.4	1.4 ± 0.8	3.4	0.018	4.9 **	0.050	3.6 *	0.038
HbA1c (%)	5.5 ± 0.3	5.5 ± 0.4	5.4 ± 0.2	5.5 ± 0.4	5.5 ± 0.2	5.4 ± 0.2	1.2	0.007	2.9	0.031	0.6	0.007
Total cardiometabolic risk	1.7 ± 5.9	0.4 ± 5.1	−2.1 ± 4.5	4.5 ± 9.3	0.9 ± 5.2	−1.7 ± 4.5	0.5	0.003	16.8 ***	0.154	3.1 *	0.033
Mental health indicators												
Burnout symptoms	2.3 ± 0.9	2.4 ± 1.1	2.4 ± 0.8	2.6 ± 0.9	3.1 ± 1.2	3.0 ± 1.2	14.1 ***	0.071	2.2	0.023	1.5	0.016
Sleep complaints	7.7 ± 4.1	7.2 ± 3.5	6.4 ± 3.6	8.8 ± 4.3	9.4 ± 5.2	9.1 ± 5.0	10.0 **	0.049	0.6	0.007	1.0	0.010
Overall mental distress	1.4 ± 2.0	1.1 ± 2.0	0.9 ± 1.8	1.8 ± 2.1	2.9 ± 3.3	2.5 ± 3.2	17.1 ***	0.081	1.1	0.011	1.0	0.011

Notes: SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; BMI = Body Mass Index; TC = Total Cholesterol; HDL = High Density Lipoproteins; LDL = Low Density Lipoproteins; TG = Triglycerides; HbA1c = Glycated Hemoglobin; ERI = Effort Reward Imbalance; CRF = Cardiorespiratory Fitness, M = Mean; SD = Standard Deviation. All analyses controlled for age, gender, education, employment rate, relationship status, children at home, caregiving responsibility, supervisor status, shift-work status, and medication intake. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

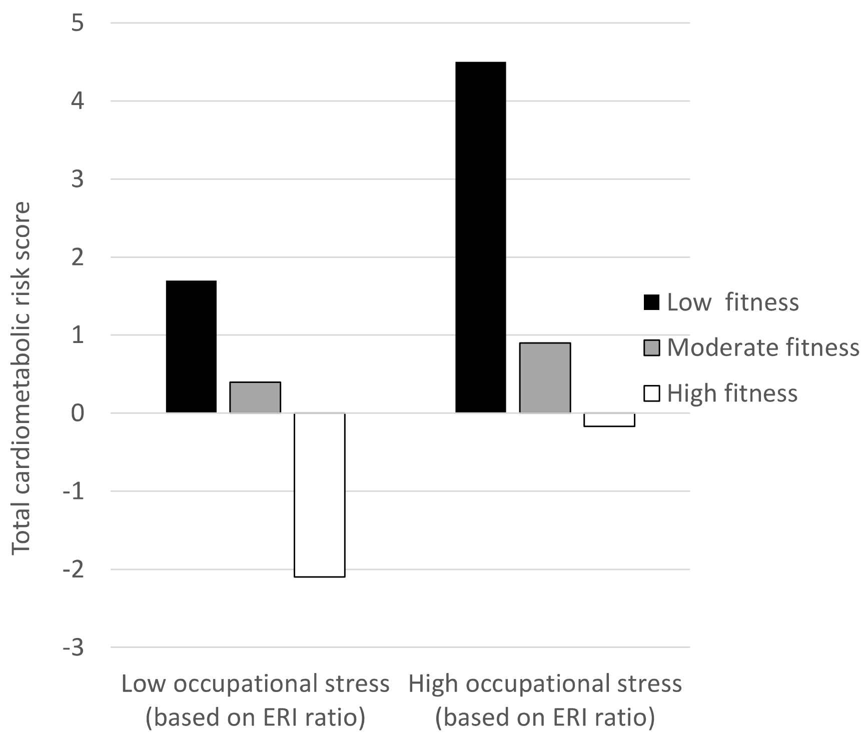

Figure 1. Graphical representation of the interaction between occupational stress (as assessed with the ERI ration) and cardiorespiratory fitness on total cardiometabolic risk. Note: Higher scores on the total cardiometabolic risk index reflect higher cardiometabolic risk.

4. Discussion

The key findings of the present study are that high cardiorespiratory fitness levels were associated with a reduced cardiometabolic risk, whereas high levels of occupational stress were associated with more burnout symptoms, sleep complaints and increased overall psychological distress. However, moderation effects of cardiorespiratory fitness on the relationship between occupational stress and the examined health outcomes were only found for the ERI ratio on total cholesterol, triglycerides and the total cardiometabolic risk index. The interaction revealed that participants with low fitness levels had a particularly high cardiometabolic risk if they were exposed to high levels of this type of occupational stress.

Our first hypothesis was that higher occupational stress would be associated with an increased cardiovascular risk, as well as decreased mental health. While the association with mental health was confirmed, in the (M)ANCOVAS, no significant differences were found between officers with low versus high occupational stress levels with regard to cardiovascular risk factors. This pattern holds true for both occupational stress models.

The fact that occupational stress was associated with mental health complaints is in line with previous research [11]. For instance, high job strain and high effort-reward imbalance predisposed the development of depression, burnout, and general mental health (GHQ-12) in prospective cohort studies with 2555 dentists [77] and 22,899 public service workers [78]. A close association between occupational stress and mental health has also been observed in police officers [26,79]. By contrast, the fact that occupational stress was unrelated to further health outcomes in the present sample was unexpected and at odds with previous research among police officers [28]. However, the existing findings are difficult to compare as researchers have used various instruments to assess occupational stress. In this context, Magnavita et al. [28] criticized that "most of the studies available provided a general non-specific measure of perceived stress that included both general and occupational stress" (p. 386).

Our second hypothesis was that higher levels of cardiorespiratory fitness would be associated with a lower cardiovascular risk, and fewer mental health complaints. Again, partial support was found for this hypothesis. Thus, in line with previous research in the police setting [80], we observed a favorable pattern of cardiovascular health markers among police officers with higher cardiovascular fitness levels. By contrast, no significant associations were found between officers' fitness levels and their mental health. Our findings were in line with previous studies showing that cardiorespiratory fitness had the potential to enhance people's cardiovascular health [81]. In a recent work by the American Heart Association, Ross et al. [82] provided a review of the rich body of evidence linking higher cardiovascular fitness to healthier levels of blood pressure, visceral adiposity, insulin sensitivity, as well as lipid and lipoprotein profiles. In a cross-sectional study with 2368 men and 2263 women, Aspenes et al. [83] measured cardiorespiratory fitness by spiroergometry on a treadmill. Despite the generally low fitness levels identified in their study population, logistic regression revealed that with every 5-mL·kg^{-1}·min^{-1} decline in VO_{2max} the odds ratio for the cardiovascular risk factor cluster increased by 56% [83]. Fernström et al. [84] reported similar findings among young adults aged 18 to 25 years.

With regard to mental health, positive associations with cardiorespiratory fitness have been reported previously. For instance, Vancampfort et al. [85] reported that people with severe mental illness have significantly lower cardiorespiratory fitness levels than healthy controls. Gerber et al. [86] further found that cardiorespiratory fitness was associated with burnout symptoms among Swedish health care workers, while Ortega et al. [87] found cardiorespiratory fitness and mental well-being to be independent predictors of mortality in a prospective study of 4888 participants. Thus, the fact that cardiorespiratory fitness and mental health were not associated with each other in the present sample was unexpected. However, the absence of this relationship can be attributed to the fact that our sample might have been healthier than those in prior research, entailing a possible ceiling effect [88]. Thus, according to ACSM standards, only 26% had poor or very poor fitness levels, whereas 44.5% had fair to excellent, and 30% even superior fitness levels. Moreover, only 4 to 7% exceeded the clinical threshold for burnout and sleep complaints, respectively, which is considerably below the rates found in previous studies [37,62].

Our third hypothesis was that cardiorespiratory fitness would moderate the relationship between occupational stress and physical/mental health indicators, but our findings only partly supported this notion. When stress was operationalized via the JDC model, no significant moderation was found. Nevertheless, when stress was operationalized via the ERI model, a significant interaction was found between occupational stress and CRF on total cholesterol, triglycerides and total cardiometabolic risk, showing that participants with low CRF had particularly high cardiometabolic risk scores when they perceived a high imbalance between efforts and reward. This finding is in line with two studies with Swedish health care workers [37] and Swiss schoolchildren [89], where similar interactions were observed. As shown in Table 1, only a few (weak) correlations were found between work-related stress on the cardiovascular health indicators. Accordingly, the potential for CRF to moderate this relationship was limited in the present sample. This may also explain why significant interaction effects were found for some, but not all cardiovascular health indicators. Furthermore, the correlations between the JDC and ERI index with the cardiovascular health outcomes pointed into different directions. This may be the reason why interaction effects were only found for the ERI ratio, whereas no such effects were observed for the JDC ratio. In a recent review, Klaperski [90] showed that physical fitness buffered the negative effects of stress in the majority of the eligible studies. However, one study cited in this review found no support for a stress-buffering effect on blood pressure and HDL-C in law enforcement officers [91]. Young [91] attributed these results to the chronicity of the measure of work stress, which might additionally not have been sensitive enough to discern physiological variations in healthy individuals. Some authors further state that physical fitness possibly buffers the acute stress response in mentally demanding occupations, rather than the long-term effects of stress [92]. Although well established in the laboratory setting [93], to date only a few studies investigated the stress-buffering effects of physical fitness on acute stress reactivity in real life. In a randomized controlled trial, von Haaren et al. [33] showed that a 20-week aerobic exercise training buffered the physiological stress response to real life stressors. The authors were able to show associations of an improved cardiorespiratory fitness and ambulatory assessed heart rate variability during two days of the examination period in 61 previously sedentary university students. Due to the current relevance of occupational stress, there is a clear demand for further evidence on this issue.

The strengths of our study are that we assessed occupational stress with standardized and validated instruments that are based on the two of the most popular and internationally accepted stress models [28]. Using an established cut-off to distinguish between participants with low versus high stress levels further allows a comparison with existing studies. Moreover, we assessed a broad range of health indicators to provide a comprehensive picture of the officers' health status. Another advantage was that cardiorespiratory fitness was assessed objectively, and that age- and gender-adjusted norms were used to classify participants in groups with low, moderate or high fitness levels. Finally, this is one of the few studies in which fitness-based stress-buffer effects were tested with objective health outcomes. This is important, as most previous studies have focused on (subjectively reported) health outcomes. Thus, in these studies the relationship between occupational stress and health might be inflated because of the shared method variance.

By contrast, some aspects limit the generalizability of our data. First, our study is cross-sectional, which precludes conclusions about causality [28,92]. Second, several blood lipid measures were considered when we calculated the overall cardiometabolic risk index [45]. However, as blood lipids were only weakly associated with cardiorespiratory fitness, it can be assumed that using our formula is likely to have resulted in an under-estimation of the association between cardiorespiratory fitness and overall cardiometabolic risk. Third, given the voluntary nature of the study, a recruitment bias is conceivable. However, the fitness categories still discriminated between participants with more or less favorable cardiometabolic risk patterns, and the ERI/JDC categories explained significant amounts of variance in the mental health outcomes. Fourth and last, physical work place characteristics were not systematically assessed in the present study [94]. However, information regarding participants' shift work status allowed us to control for the fact of whether officers engaged in office or field service.

5. Conclusions

Our findings suggest that occupational stress is negatively associated with police officers' mental wellbeing. Our results also suggest that occupational stress may be more closely related to psychological health than physical health. Therefore, work health programs for police officers should consider the early screening of burnout, sleep disturbances, and overall mental well-being. CRF, as measured with a submaximal bicycle test, appears to be a relevant marker for cardiovascular health in police officers. Moreover, officers with moderate or high CRF levels have a lower overall cardiometabolic risk when they perceive a strong imbalance between their invested efforts and their reward at work. To increase cardiovascular health, we encourage the inclusion of fitness tests in routine health checks, and the promotion of physical activity to further increase the fitness levels among police officers.

Author Contributions: All authors made substantial contributions to this paper. R.S., U.P., and M.G. made substantial contributions to the conception and the design of the study. R.S., F.C., and S.L. and were responsible for the acquisition and the storage of data. R.S., FC, S.B., and M.G. were responsible for the analysis and interpretation of data. F.C. and U.P. monitored the writing process and revised the scientific standard. R.S. and M.G. drafted the manuscript. F.C. and S.B. wrote sections of the manuscript. F.C., S.L., S.B., and U.P. critically reviewed and revised the initial draft. All authors have approved the final version of the submitted manuscript.

Funding: This research received no external funding.

Acknowledgments: We thank the police force of the Canton of Basel-City for their cooperativeness and support of our study, and all participants for their willingness to participate.

Conflicts of Interest: All authors declare no competing interests.

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3.4 Publication 4: Prospective analysis on stress-buffering effects of physical activity and cardiorespiratory fitness on metabolic syndrome

Title:

Stress-Buffering Effects of Physical Activity and Cardiorespiratory Fitness on Metabolic Syndrome: a Prospective Study in Police Officers

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Published in:

PLoS ONE 15(7): e0236526.

Publication available at:

https://doi.org/10.1371/journal.pone.0236526

PLOS ONE

RESEARCH ARTICLE

Stress-buffering effects of physical activity and cardiorespiratory fitness on metabolic syndrome: A prospective study in police officers

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OPEN ACCESS

Citation: Schilling R, Colledge F, Pühse U, Gerber M (2020) Stress-buffering effects of physical activity and cardiorespiratory fitness on metabolic syndrome: A prospective study in police officers. PLoS ONE 15(7): e0236526. https://doi.org/10.1371/journal.pone.0236526

Editor: Matteo Vandoni, University of Pavia, ITALY

Received: March 26, 2020

Accepted: July 7, 2020

Published: July 28, 2020

Peer Review History: PLOS recognizes the benefits of transparency in the peer review process; therefore, we enable the publication of all of the content of peer review and author responses alongside final, published articles. The editorial history of this article is available here: https://doi.org/10.1371/journal.pone.0236526

Data Availability Statement: The datasets used and/or analysed during the current study are available on reasonable request from Ms. Nienke Jones (Nienke.jones@bs.ch; +41 61 268 13 54) via the Ethics Committee of Northwestern and Central

Abstract

Metabolic syndrome (MetS) is a worldwide health concern related to cardiovascular disease. Stress at work increases the risk for MetS, whereas physical activity and cardiorespiratory fitness (CF) have been shown to be potential buffers against stress. The aim of this study was to test the stress-buffering effects of physical activity and CF on the relationship between work stress and MetS. In a prospective study, we followed 97 police officers (mean age = 39.7 years; mean body mass index = 25.74 kg/m^2) over one year and assessed MetS, as defined by the National Cholesterol Education Program Adult Treatment Panel III. Stress at work was measured with the Job Content Questionnaire, as well as the Effort-Reward Imbalance Questionnaire. Physical activity was assessed objectively via 7-day accelerometry. CF was assessed with the Åstrand bicycle ergometer test. Hierarchical linear regression models were carried out to predict MetS at follow-up (mean overall MetS score = 1.22), after controlling for baseline levels and sociodemographic background (mean overall MetS score = 1.19). Higher CF levels were significantly associated with lower MetS risk at follow-up (β = -.38). By contrast, no main effects were found for physical activity and work stress. However, high effort and demand were significantly correlated with increased blood pressure (effort: r = .23 for systolic blood pressure; r = .21 for diastolic blood pressure) and waist circumference (effort: r = .26; demand: r = .23). Moreover, no significant interaction effects occurred between work stress and CF/physical activity. The results emphasize the importance of high levels of CF in the prevention of MetS in police officers. Accordingly, provision of regular training opportunities and repeated CF testing should be considered as a strategy in overall corporate health promotion.

Introduction

Metabolic syndrome (MetS) has become a prominent health concern in industrialized countries [1, 2]. MetS is a cluster of symptoms, consisting of abdominal adiposity, reduced glucose tolerance, dyslipidemia, and hypertension [1]. While accepted and clinically used definitions

Switzerland (EKNZ). At the time of obtaining ethical clearance for the present study from the EKNZ, and in line with Swiss laws, we stated that only authorized researchers who are directly involved in the present project will have access to the raw data. Accordingly, and in line with this statement, we cannot grant access to the data for third parties, unless this is officially approved by the EKNZ.

Funding: The authors received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

differ slightly, scholars generally agree on strong associations between MetS and cardiovascular diseases [1, 3]. Widely accepted criteria for MetS were established by the National Cholesterol Education Program [4]. The systematic review and meta-analysis by Mottillo et al. [5] concluded that meeting these criteria was linked to a 100 percent increased risk for cardiovascular mortality.

A chronically elevated level of stress is regarded as a salient risk factor for MetS [6–8]. In Western societies, the place of work constitutes a major source of stress for many adults [9]. Two theoretical work stress models dominate current stress research [10]. Firstly, the job strain model, which holds that stress arises from a discrepancy between demands and control [11]. Secondly, the effort-reward imbalance model, which assumes that stress is due to a mismatch between commitment and gratification [12]. Both models have shown that increased stress is associated with a heightened risk of MetS [13–15]. For example, Chandola et al. [14] revealed the risk for MetS is twice as high in participants who report high vs. low levels of job strain over the span of 14 years.

Police officers encounter a multitude of psychosocial stressors during their work [16]. In a study with American police officers, Violanti et al. [17] showed that night shifts, fewer sleeping hours and overtime might contribute to the development of MetS in police officers. However, police officers form a heterogeneous population, and it is suggested that individual stress perceptions play a more important role than their specific divisional tasks [18]. For example, Gerber et al. [19] reported closer links between police officers' health and subjective stress perception than for shift work status. Similarly, Garbarino and Magnavita [20] followed police officers for 5 years, and found that high rates of work stress (job strain and effort-reward imbalance) were associated with a 2.7 times higher risk for the development of MetS. Prevalence rates of MetS are rising [21–23], and police officers have been found to be at increased risk compared to the general population [24]. Despite these findings, however, prospective studies examining the association between work stress and MetS are still relatively rare [15].

Regular physical activity and resulting cardiorespiratory fitness (CF) have been shown to enhance resilience against stress and stress-related disease [25–29], including police officers [30, 31]. However, with a few exceptions [27], most of these studies used self-reported health indicators, and none have focused on MetS. Therefore, the aim of the present study is to investigate potentially stress-buffering effects of CF on MetS. The study uses a 1-year prospective design to assess the effects of work stress on the concurrent and future level of MetS. As noted above, the occupation of policing is known to involve a stressful work environment and an increased risk for MetS [24, 32, 33].

Based on the literature presented above, three hypotheses will be tested in the present paper: First, high levels of CF and physical activity are negatively associated with MetS [34]. Second, high levels of work stress are positively associated with MetS [35]. Third, CF and physical activity moderate (buffer) the association between occupational stress and MetS. In other words, among police officers with high stress levels, those who are more physically active or fit are less likely to have or develop MetS [26].

Methods

Study design, participants and procedures

The present study was designed as a 12-month prospective investigation with two data assessments. The present sample consisted of police officers from Basel, Switzerland. The recruitment involved different workplace dissemination channels, consisting of videos, news journals, flyers, and information during team meetings. These advertisements promoted a comprehensive health check (including MetS), work stress assessment, cardiorespiratory fitness test, and 7-day actigraphy, all of which were performed twice within one year. Anyone interested was invited to an e-learning program that provided information about the study background, measurements, risks, and benefits. Participation was voluntary without financial incentives. However, all activities related to the study could be performed during working hours, and participants received a personalized health profile. Furthermore, a voluntary life-style-coaching was offered to all participants. Prior to the health check, participants provided written informed consent and confirmed their physical eligibility based on the Physical Activity Readiness Questionnaire (ACSM) [36]. In case of uncertainty, a general practitioner was consulted. If (moderate-to-vigorous-intensity) physical activity was contraindicated, only non-physical measurements were performed. All study procedures followed the principles of the Declaration of Helsinki; the study was approved by the local ethics committee Ethikkommission Nordwest- und Zentralschweiz (EKNZ: Project-ID: 2017–01477).

The health and fitness checks took place between October 2017 and April 2019, in a laboratory at the education and training center of the police force. The specific room was exclusively reserved for the study across the entire study period. The laboratory sessions lasted approximately 60 minutes. On the same day, participants answered an online questionnaire addressing their socio-demographic background and their occupational stress level. Furthermore, participants answered questionnaires on burnout symptoms, overall mental health, and sleep complaints (not discussed in this paper). Following the laboratory session, participants were asked to wear an accelerometer for seven consecutive days to measure physical activity. An additional smartphone-based real-life measurement of emotions and stressors was performed during the first two days after the laboratory session; this data will be presented elsewhere.

Measures

Metabolic syndrome (MetS). Our criteria for MetS followed the recommendations of the National Cholesterol Education Program Adult Treatment Panel III (NCEP III): (i) waist circumference > 102 for men, and > 88 cm for women; (ii) triglyceride level > 1.7 mmol/l; (iii) HDL cholesterol of < 1.0 mmol/l for men and < 1.3 mmol/l for women; (iv) systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg; and (v) blood HbA1c level > 6.1 percent [4]. Based on whether these cut-off values were exceeded (score = 1) or not (score = 0), we calculated an overall MetS sum score for further analyses. NCEP III describes the presence of three or more of the risk determinants as MetS.

In our study, the assessment of each MetS component was performed as follows: We assessed waist circumference following the World Health Organization (WHO) STEPS Manual [37]. Participants were asked to stand and breath in a relaxed way. A tape measure was applied in horizontal position in the middle of the inferior margin of the lowest rib and the crest of the ilium. The measurement was taken at the end of the expiration. Blood samples were drawn via finger prick following WHO guidelines [38]. The sample was instantly analyzed with Alere Afinion AS100 Analyzer (Abbott Diagnostics, Alere Technologies, Rodeløkka NO-0504 Oslo, Norway). HbA1c, high-density lipoprotein cholesterol (HDL-C), and triglycerides (TG) were assessed for further analysis. Validity and reliability have been described previously [39]. Lipid and glucose panel controls were frequently used to ensure the reliability of the devices. Systolic and diastolic blood pressure were measured in a sitting position with the OMRON M500 (OMRON Healthcare Co. Ltd. 53, Kunotsubo, Terado-cho, Muko, Kyoto 617–0002 Japan). The device was attached to the left arm. Two measurements were taken, spaced apart by 3 minutes. Systolic and diastolic blood pressure were noted and the mean was calculated for further analyses.

Work stress. Work stress was assessed using the Job Content Questionnaire (JCQ) [40] as well as the Effort-Reward Imbalance (ERI) Questionnaire [12]. The JCQ consists of a demand and a control scale. The demands were assessed with five items (e.g. 'My job requires working very hard.'), and answers were given on a 4-point Likert scale (1 = never to 4 = often). The control subscale consisted of six items (e.g. 'I have freedom to make decisions about my job.') with the same response options as for the demands subscale. The items were summed for each subscale and a job demand and control ratio (JDC ratio) was computed using the formula: demand / control * 0.8333. Values above 1 indicate work stress with possible negative effects on health [40]. The validity and reliability of the JCQ has been described previously [41]. The effort scale of the ERI questionnaire consists of five items (e.g. 'I have a lot responsibility in my job.'), whereas the reward scale comprises eleven items (e.g. 'Considering all my efforts and achievements, my job promotions are adequate.'). All items were answered on a 5-point Likert scale from 1 (none) to 5 (very high). Each subscale was summed and an overall ratio was calculated with the formula: effort / reward * 0.4545. An ERI ratio higher than one has been typified as high work stress [12]. Reliability and validity of both job stress questionnaires have been described previously [41, 42]. Reviews of prospective cohort studies have shown an increased risk for CVD in individuals with high work stress, as measured with the JCQ or the ERI questionnaire [43, 44].

Physical activity. Physical activity was assessed objectively with accelerometry. Accelerometry was carried out using ecgMove3 sensors (movisens GmbH, Karlsruhe, Germany). The ecgMove3 records 3-dimensional acceleration (63 Hz) and barometric altitude (8 Hz). Evidence for the validity and reliability has been provided previously [45, 46]. At the end of the laboratory session, participants were asked to put on the device, which was worn on a textile dry electrode chest belt. Data was saved on an internal memory and readout after the device was returned. Data was processed with the DataAnalyzer (movisens GmbH, Karlsruhe, Germany). The software provides a report of energy expenditure, steps, activity classes, and non-wear time. Following Troiano et al. [47], days with $\geq$ 10 hours of wear time were considered valid. Datasets with $\geq$ 5 valid days were included in the data analysis. The average day values (minutes per valid day) of moderate-to-vigorous physical activity (MVPA) was used for further calculations.

Cardiorespiratory fitness (CF). CF was assessed with the widely used Åstrand submaximal bicycle test [48]. The test accurately estimates maximal oxygen consumption (VO_2max) based on standardized extrapolations of heart rates at certain resistances [48–50]. Participants were instructed to avoid any strenuous activity 24 hours prior to the testing. Furthermore, no meals and liquids were to be consumed within three hours prior to the testing. For the test, participants wore a POLAR (Polar Electro, Kempele, Finland) heart rate monitor. Standardized starting workloads (men = 150 Watts; women = 100 Watts) were adjusted so that the heart rate remains in predefined limits. These limits were 130–160 bpm for participants $<$ 40 years of age, and 120–150 (bpm) for participants $\geq$ 40 years. Cycling cadence was set at 60 rotations per minute. Borg ratings were assessed after every minute and participants were controlled for cancellation criteria [51]. After six minutes of cycling, the test ended. Participants were only asked to proceed for another minute if the heart rate of the last two minutes varied by more than 5 beats per minute. The resulting final workload and mean heart rate of the last two minutes were translated into age and gender adjusted VO_2max (ml/kg/min) levels. Following the American College of Sports Medicine (ACSM), participants' CF were classified as 'very poor', 'poor', 'fair', 'good', 'excellent', and 'superior' [51].

Statistical analyses

Descriptive statistics were calculated for all main study variables at baseline and additionally for the various MetS components at follow-up (data on physical PA and CF at follow-up was not considered in the present data analysis). Furthermore, cross-sectional bivariate correlations are provided for physical activity (accelerometry), CF, and occupational stress (JDC ratio, ERI ratio), with the MetS overall score at baseline and follow-up. To explore possible stress-buffering effects of physical activity and CF on MetS, we provide the results of several hierarchical linear regressions. Following procedures by Aiken and West [52], stress-buffering effects were determined as significant interaction terms in a moderation model. Separate moderation models were tested for objectively assessed physical activity, as well as for CF, and their respective interactions with the two work stress indicators. In order to find out which variables were initially associated, we first performed cross-sectional (baseline) analyses. We then computed prospective analyses, accounting for the baseline level of MetS, in order to establish temporal precedence.

For cross-sectional analyses, we performed 4-step hierarchical linear regressions, based on participants' baseline scores. The variables were entered in the regression equation in the following order: socio-demographic background (step 1), work stress (step 2), physical activity (or CF) (step 3), interaction terms between JDC ratio and ERI ratio, physical activity (or CF) and JDC ratio, and physical activity (or CF) and ERI ratio (step 4). All variables were centered (z-standardized) before the interaction terms were calculated.

For the prospective analyses (with MetS at follow-up as dependent variable), we performed a series of 5-step hierarchical linear regression analyses. The variables were entered in the regression equation in the following order: socio-demographic background (step 1), baseline MetS score (step 2), work stress (step 3), physical activity (or CF) (step 4), interaction terms between JDC ratio and ERI ratio, physical activity (or CF) and JDC ratio, and physical activity (or CF) and ERI ratio (step 5). Again, all variables were centered (z-standardized) before the interaction terms were calculated. In the results section, we report the stepwise changes in R^2, and the standardized regression weights for each predictor variable in the final models. All statistical analyses were performed using SPSS 26 (IBM Corporation, Armonk NY, USA), and p-values of $< .05$ were considered as statistically significant.

Results

Sample description

Approximately 1000 police force employees received the study advertisement, which they could view voluntarily. From these, 227 officers (approximately 23%) agreed to obtain background information via the e-learning program, and 201 officers finally decided to participate in the cross-sectional study (88%). Of these, 97 (48.3%) officers also took part in the follow-up data assessment and were considered for data analyses. Among those participants with complete baseline and follow-up data, the mean age was 39.7 years (± 9.59), and the mean body mass index was 25.74 kg/m^2 (± 3.68). This sample was composed of 32 women (33%) and 65 men (67%). In sum, 74.2 percent (n = 72) of the participants reported being married or in a relationship, 11.3 percent (n = 11) had higher education (university or college), 34.0 percent (n = 33) had completed high school, and 48.5 percent (n = 47) had basic vocational training. Almost half of the participants (43.3%, n = 42) reported having children living at home, whereas 2.1 percent (n = 2) had current care responsibilities. In total, 44.3 percent (n = 43) of participants were involved in shift work and 15.6 percent (n = 15) were employed in middle and upper ranks of the department. The average employment rate was 80.5 percent, and 13.4

percent (n = 13) of the participants reported current intake of medication. Current smoking was reported by 19.6 percent (n = 19), weekly intake of alcoholic drinks was reported by 63.9 percent (n = 62). Finally, 48.5 percent (n = 47) of the participants stated that they do not think that they are physically active enough to maintain good health. As shown in Table 1, at baseline, participants who were lost until follow-up did not differ significantly from participants who participated in the follow-up data assessment in any of the sociodemographic background variables or the predictor and outcome variables. In the present paper, only data is considered from those 97 participants who took part in the follow-up data assessment, even when cross-sectional associations are reported.

Descriptive statistics and bivariate correlations

Descriptive statistics for the participants who took part in the follow-up data assessment ($N = 97$) are presented in Table 2. At baseline, 7.2 percent ($n = 7$) of the participants had ≥ 3 out of 5 criteria for MetS, whereas 8.3 percent ($n = 8$) fulfilled ≥ 3 criteria at follow-up. With regard to work stress at baseline, more than half of the participants (51.5%, $n = 50$) had a JDC ratio ≥ 1, whereas 44.3 percent ($n = 43$) had an ERI ratio ≥ 1. Based on the accelerometry data, the present sample was highly active. The mean levels in the present sample appeared to be approximately 3 to 7 times higher than the WHO recommendations of ≥ 150 minutes of weekly moderate-to-vigorous physical activity [53]. Furthermore, the classification of CF levels revealed that 25.8 percent ($n = 25$) had poor to very poor fitness, 24.8 percent ($n = 24$) showed fair to good fitness, whereas 48.5 percent ($n = 47$) reached the level of excellent to superior fitness.

Table 3 shows the correlations between physical activity, CF, and work stress with the components of MetS (both at baseline and follow-up). A significant and negative correlation was found between objectively assessed physical activity and blood sugar, both at baseline and follow-up. The negative correlation between physical activity and the overall score of MetS only reached significance for the follow-up measurement. Higher CF was significantly associated with more favorable scores in most MetS components. More precisely, CF was significantly and negatively correlated with waist circumference, blood lipids, blood sugar, and the overall MetS score at baseline; and with waist circumference, blood lipids, diastolic blood pressure, and the overall MetS score at follow-up.

Neither the JDC ratio, nor the ERI ratio, were significantly associated with the various components of MetS, at baseline or at follow-up. The demand subscale was only significantly associated with waist circumference at follow-up. Interestingly, the control subscale was positively associated with several of the MetS outcomes and reached the level of significance for diastolic blood pressure at follow-up. The effort subscale was significantly and positively related to systolic and diastolic blood pressure at baseline, whereas significant (positive) correlations with waist circumference and systolic and diastolic blood pressure were observed at follow-up. The reward subscale was not significantly associated with any of the outcomes.

Cross-sectional and prospective hierarchical linear regressions

The results of the hierarchical linear regression analyses are reported in Tables 4 and 5. As shown in Table 4, the cross-sectional regression analyses explained between 18 and 30 percent in the dependent variable (overall MetS score). Nevertheless, the analyses revealed significant interaction effects only between the two job stress questionnaires, whereas no stress-buffering effects of physical activity or CF appeared to be present in the data. Education level was significantly and negatively associated with the overall MetS score. Age was positively associated with the overall MetS score; however, this association did not reach significance in the final

Table 1. Differences between participants who were lost to follow-up and participants who completed both data assessments in sociodemographic background and predictor and outcome variables.

Baseline	All participants			Participants lost to follow-up			Participants who completed the follow-up					
Socio-demographics	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*t*	*p*	*d*
Age (years)	201	38.55	10.13	104	37.45	10.55	97	39.73	9.59	-1.60	.11	-0.23
Relationship status (single = 1, relationship = 2)	189	1.80	0.40	97	1.81	0.39	92	1.78	0.41	0.54	.59	0.08
Education (1–7)	188	3.15	1.51	95	3.14	1.55	93	3.17	1.48	-0.16	.87	-0.02
Children (yes = 1; no = 2)	190	1.57	0.50	97	1.59	0.49	93	1.55	0.50	0.54	.59	0.08
Weight (in kg)	201	78.98	14.29	104	79.21	13.50	97	78.74	15.15	0.23	.82	0.03
Body Mass Index (kg/m^2)	201	25.78	3.63	104	25.81	3.59	97	25.74	3.68	0.14	.89	0.02
Gender (male = 0, female = 1)	201	0.36	0.48	104	0.39	0.49	97	0.32	0.47	1.10	.27	0.15
Shift work (yes = 0, no = 1)	191	0.57	0.50	96	0.53	0.50	95	0.60	0.49	-0.96	.34	-0.14
Smoking (no = 0, yes = 1)	189	0.20	0.40	96	0.19	0.39	93	0.20	0.41	-0.29	.77	-0.03
Drinking days per week	189	1.33	1.38	96	1.34	1.35	93	1.31	1.42	0.16	.87	0.02
Physical activity and CF	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*t*	*p*	*d*
Accelerometry (MVPA min/week)	171	410.63	174.3	86	403.27	154.21	85	418.18	193.13	-0.56	.58	-0.09
CF (estimated VO_2max in ml/kg/min)	200	45.02	11.22	104	43.99	10.93	96	46.14	11.48	-1.35	.18	-0.19
Work stress	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*t*	*p*	*d*
JDC ratio	190	0.96	0.19	97	0.94	0.19	93	0.98	0.20	-1.21	.23	-0.21
ERI ratio	190	0.89	0.27	97	0.86	0.23	93	0.93	0.31	-1.55	.12	-0.26
Metabolic syndrome	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*t*	*p*	*d*
Waist circumference (cm)	199	91.07	11.27	103	91.00	11.32	96	91.14	11.27	-0.08	.94	-0.01
TG (mmol·L–1)	201	1.69	1.17	104	1.63	1.04	97	1.75	1.30	-0.74	.46	-0.10
HDL-C (mmol·L–1)	200	1.82	0.40	104	1.80	0.41	96	1.84	0.40	-0.65	.52	-1.00
SBP (mm Hg)	201	129.57	13.17	104	129.14	13.29	97	130.04	13.09	-0.48	.63	-0.07
DBP (mm Hg)	201	85.10	10.25	104	84.96	10.07	97	85.26	10.49	-0.21	.84	-0.03
HbA1c (%)	201	5.45	0.29	104	5.46	0.30	97	5.43	0.28	0.67	.50	0.10
Overall MetS score	201	1.16	0.94	104	1.15	0.95	97	1.19	0.96	-0.16	.87	-0.04

M = Mean; *SD* = Standard Deviation; *d* = Effektstärke Cohen's *d*; Skew = Skewness; Kurt = Kurtosis; MetS (%) = Percentage of participants that met the specific criterion of Metabolic Syndrome; TG = Triglyceride; HDL-C = High-Density Lipoprotein Cholesterol; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; HbA1c = Glycated Hemoglobin; MetS = Metabolic Syndrome; JDC = Job Demand and Control; ERI = Effort-Reward Imbalance; MVPA = Accelerometer-based Moderate to Vigorous Physical Activity; CF = Cardiorespiratory Fitness. Differences in *N* are due to different numbers of missing values for different variables. Sample size is lower for MVPA than CF because some participants had to be excluded from data analyses due to insufficient accelerometer wear-time.

https://doi.org/10.1371/journal.pone.0236526.t001

model. These sociodemographic variables explained 10 percent of variance in the overall MetS score in both models. The job stress questionnaires did not significantly explain additional variance in either of the models. Although both MVPA (β = -.17) and CF (β = -.38) were negatively associated with the overall MetS score, only the association for CF reached significance ($p < .01$), with CF explaining 12 percent of variance in the final model.

Fig 1 illustrates the significant interaction between the two work stress questionnaires in the cross-sectional analysis. With an increase in the ERI ratio, the group with a higher JDC ratio showed a greater increase in the overall MetS score.

The prospective hierarchical linear regression analyses are presented in Table 5. The level of explained variance in the dependent variable (overall MetS score) varied between 38 and 39 percent. Counter to the cross-sectional analyses, no significant interaction effects occurred in the prospective analyses. This indicates that differences in MetS at follow-up were not influenced by the interplay between baseline scores of job stress, physical activity, and CF. In all three models, relationship status significantly predicted the overall MetS score at follow-up.

Table 2. Descriptive statistics for main study variables at baseline and follow-up for the participants who took part in the follow-up data assessment (*N* = 97).

Baseline							
Metabolic syndrome	*n*	*M*	*SD*	Range	Skew	Kurt	MetS (%)
Waist circumference (cm)	96	91.14	11.27	61.50–126.00	0.48	1.26	20 (20.6)
TG ($mmol \cdot L^{-1}$)	97	1.75	1.30	0.51–7.35	2.52	7.10	34 (35.1)
HDL-C ($mmol \cdot L^{-1}$)	96	1.84	0.40	0.93–2.59	0.02	-0.54	2 (2.1)
SBP (mm Hg)	97	130.04	13.09	107.00–172.0	0.59	0.44	59 (60.8)
DBP (mm Hg)	97	85.26	10.49	63.50–118.0	0.21	0.04	
HbA1c (%)	97	5.43	0.28	4.90–6.80	1.65	6.36	1 (1.0)
Overall MetS score	97	1.19	0.96	0.00–4.00	0.55	0.07	
Work stress							
JDC ratio	93	0.98	0.20	0.54–1.50	0.60	0.25	
ERI ratio	93	0.93	0.31	0.33–2.02	0.79	1.01	
Physical activity and CF							
Accelerometry (MVPA min/week)	85	418.18	193.13	49–1389	1.77	6.91	
CF (estimated VO_2max in ml/kg/min)	96	46.14	11.48	24.20–89.40	0.69	1.09	
Follow-up							
Metabolic syndrome		*M*	*SD*	Range	Skew	Kurt	MetS (%)
Waist circumference (cm)	96	90.87	10.90	72.0–127.0	0.94	1.43	18 (18.6)
TG ($mmol \cdot L^{-1}$)	97	1.84	0.98	0.7–7.4	2.69	11.05	47 (48.5)
HDL-C ($mmol \cdot L^{-1}$)	96	1.73	0.56	0.9–5.5	3.34	20.64	5 (5.2)
SBP (mm Hg)	97	127.46	13.49	103.0–172.0	0.71	0.73	47 (48.5)
DBP (mm Hg)	97	82.41	10.03	62.5–112.5	0.61	0.45	
HbA1c (%)	96	5.23	0.92	4.8–6.8	0.95	0.82	2 (2.1)
Overall MetS score	97	1.22	0.92	0–4	0.92	-0.11	

M = Mean; *SD* = Standard Deviation; Skew = Skewness; Kurt = Kurtosis; MetS (%) = Percentage of participants that met the specific criterion of Metabolic Syndrome; TG = Triglyceride; HDL-C = High-Density Lipoprotein Cholesterol; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; HbA1c = Glycated Hemoglobin; MetS = Metabolic Syndrome; JDC = Job Demand and Control; ERI = Effort-Reward Imbalance; MVPA = Accelerometer-based Moderate to Vigorous Physical Activity; CF = Cardiorespiratory Fitness. Differences in *N* are due to different numbers of missing values for different variables. Sample size is lower for MVPA than CF because some participants had to be excluded from data analyses due to insufficient accelerometer wear-time.

https://doi.org/10.1371/journal.pone.0236526.t002

Being in a relationship was negatively associated with the overall MetS score after one year. Furthermore, the stepwise inclusion of baseline values of the overall MetS score significantly explained between 12 and 14 percent of variance in the two models, showing that higher MetS scores at baseline were associated with higher MetS scores at follow-up. By contrast, the work stress measures did not significantly predict the overall MetS score after one year. MVPA was negatively associated with the overall MetS score after one year ($\beta = -.18$). However, the association did not reach statistical significance. By contrast, CF ($\beta = -.25$, $p < .05$) was significantly and negatively associated with the overall MetS score after one year, explaining 9 percent of variance in the model. This association is presented in Fig 2.

Differences between fitness categories in MetS

Based on the significant main effects of CF in both the cross-sectional and prospective analyses, we provide further information describing this association. The following figures show the

Table 3. Correlations between physical activity, cardiorespiratory fitness, work stress with cardiometabolic risk factors at baseline and follow-up, for the participants who took part in the follow-up data assessment.

Baseline	MVPA	CF	JDC ratio	ERI ratio	Demand	Control	Effort	Reward
Waist circumference (cm)	-.21	-.39**	.06	.13	.18	.06	.19	-.02
n	84	95	92	92	92	92	92	92
TG (mmol·L^{-1})	-.04	-.26**	-.02	.07	.16	.15	.09	-.05
n	85	96	93	93	93	93	93	93
HDL-C (mmol·L^{-1})	.01	.28**	-.16	-.11	-.13	.09	-.13	.04
n	84	95	92	92	92	92	92	92
SBP (mm Hg)	-.21	-.18	-.05	.20	.11	.12	.25*	-.08
n	85	96	93	93	93	93	93	93
DBP (mm Hg)	-.21	-.25*	-.05	.19	.12	.15	.24*	-.05
n	85	96	93	93	93	93	93	93
HbA1c (%)	-.27*	-.34**	-.12	.05	-.01	.13	.01	-.05
n	85	95	93	93	93	93	93	93
Overall MetS score	-.14	-.38**	-.05	.10	.12	.16	.17	.02
n	85	96	93	93	93	93	93	93
Follow-up	MVPA	CF	JDC ratio	ERI ratio	Demand	Control	Effort	Reward
Waist circumference (cm)	-.17	-.41**	.02	.20	.23*	.17	.26*	-.06
n	84	95	92	92	92	92	92	92
TG (mmol·L^{-1})	-.15	-.19	.00	.10	.16	.10	.07	-.11
n	85	96	93	93	93	93	93	93
HDL-C (mmol·L^{-1})	.08	.27**	.02	.07	.14	.08	-.01	-.13
n	85	96	93	93	93	93	93	93
SBP (mm Hg)	-.13	-.19	-.04	.19	.13	.13	.23*	-.08
n	85	96	93	93	93	93	93	93
DBP (mm Hg)	-.12	-.25**	-.12	.17	.08	.21*	.21*	-.08
n	85	96	93	93	93	93	93	93
HbA1c (%)	-.29**	-.26*	-.16	.00	-.08	.08	-.08	-.09
n	84	95	92	92	92	92	92	92
Overall MetS score	-.21*	-.38**	-.10	.10	.08	.19	.12	-.03
n	85	96	93	93	93	93	93	93

MVPA = Accelerometer-based Moderate-to-Vigorous Physical Activity; CF = Cardiorespiratory Fitness; JDC = Job Demand and Control; ERI = Effort-Reward Imbalance; TG = Triglyceride; HDL-C = High-Density Lipoprotein Cholesterol; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; HbA1c = Glycated Hemoglobin; MetS = Metabolic Syndrome. Differences in *N* are due to different numbers of missing values for different variables. Sample size is lower for MVPA than CF because some participants had to be excluded from data analyses due to insufficient accelerometer wear-time.

* $p < .05$;

** $p < .01$.

https://doi.org/10.1371/journal.pone.0236526.t003

differences between fitness levels as classified by the ACSM in regard to their overall MetS score at baseline (Fig 3A) and follow-up (Fig 3B).

Discussion

The aim of the present paper was to assess whether physical activity and cardiorespiratory fitness moderate the interplay between work stress and MetS. We followed 97 police officers for one year. Our results revealed no significant stress-buffering effects of physical activity or cardiorespiratory fitness. However, higher levels of CF significantly predicted lower levels of

Table 4. Cross-sectional hierarchical linear regression with overall MetS score at baseline as dependent variable, for the participants who took part in the follow-up data assessment.

	Stress-buffering variable			
	MVPA (*n* = 82)		CF (VO_2max) (*n* = 92)	
	ΔR²	β	*ΔR²*	β
Step 1[a]	.10*		.10**	
Age		.15		.15
Education		-.28*		-.22*
Step 2	.01		.01	
JDC ratio		-.11		-.02
ERI ratio		-.02		.05
Step 3	.02		.12**	
Stress-buffering variable		-.17		-.38**
Step 4	.05		.07*	
JDC ratio x ERI ratio		.21		.25**
Stress-buffer x JDC ratio		.07		.04
Stress-buffer x ERI ratio		-.19		-.17
Total R^2	.18*		.30**	

MVPA = Accelerometer-based Moderate-to-Vigorous Physical Activity; CF = Cardiorespiratory Fitness; JDC = Job Demand and Control; ERI = Effort-Reward Imbalance. [a]Only covariates were retained in the final model for which a significant bivariate association was found in the correlation analyses. Differences in *N* are due to different numbers of missing values for different variables. Sample size is lower for MVPA than CF because some participants had to be excluded from data analyses due to insufficient accelerometer wear-time.

* $p < .05$;

** $p < .01$.

https://doi.org/10.1371/journal.pone.0236526.t004

MetS in the regression analyses. Neither job stress, nor physical activity were significant predictors of MetS after one year. We formulated three hypotheses, which will now be discussed in turn.

In our first hypothesis, we expected that work stress would be associated with MetS. Whereas the two job stress questionnaires cross-sectionally correlated with the outcome as expected, these correlations only reached significance for subscale values. The strongest correlations occurred for waist circumference, and blood pressure. This is in line with previous evidence showing that the association between job stress and MetS was mediated by obesity [54]. However, we did not find a significant direct effect between the JDC ratio or ERI ratio and MetS in the regression analyses. This result does not match with the strong associations reported in previous studies. Data from the Whitehall study showed that chronic work stress (job strain and effort-reward imbalance) over 14 years was related to an increased risk for MetS of 2.25 OR (95% confidence interval = 1.31 to 3.85) [14]. Another example is a review of prospective cohort studies with an approximately 8-year follow-up by Siegrist [55]. In this review, the risk for Type II diabetes was estimated to be 160 percent for high effort-reward imbalance [55]. Shorter follow-up durations, however, have shown weaker associations. In a two-year follow-up study by Loerbroks et al. [15], job stress (ERI) was associated with an adjusted risk for MetS of 1.20; with a 95 percent confidence interval of 1.01 to 1.42. Hence, the duration of the present study, but also the low incidence of MetS, might have contributed to lower detectable effects.

The above-mentioned correlations between job stress and the components of MetS in the present study mainly applied for the demand (Job Content Questionnaire) and effort (Effort-

Table 5. Prospective hierarchical linear regression with overall MetS scores at follow-up as dependent variable, for the participants who took part in the follow-up data assessment.

	Stress-buffering variable			
	MVPA (n = 81)		CF (VO_2max) (n = 91)	
	ΔR^2	β	ΔR^2	β
Step 1[a]	.20**		.15**	
Relationship status		-.33**		-.25**
Education		-.11		-.11
Step 2	.12**		.14**	
Overall MetS score at baseline		.37**		.33**
Step 3	.01		.01	
JDC ratio		-.05		-.06
ERI ratio		.00		-.01
Step 4	.02		.09**	
Stress-buffering variable		-.18		-.25*
Step 5	.03		.01	
JDC ratio x ERI ratio		-.17		-.09
Stress-buffer x JDC ratio		-.05		.07
Stress-buffer x ERI ratio		-.03		-.05
Total R^2	.38**		.39**	

MetS = Metabolic Syndrome; MVPA = Accelerometer-based Moderate-to-Vigorous Physical Activity; CF = Cardiorespiratory Fitness; JDC = Job Demand and Control; ERI = Effort-Reward Imbalance. [a]Only covariates were retained in the final model for which a significant bivariate association was found in the correlation analyses. Differences in N are due to different numbers of missing values for different variables. Sample size is lower for MVPA than CF because some participants had to be excluded from data analyses due to insufficient accelerometer wear-time.

* $p < .05$;

** $p < .01$.

https://doi.org/10.1371/journal.pone.0236526.t005

Reward Imbalance Questionnaire) subscales. Garbarino and Magnavita [20] found similar results in a sample of highly stressed police officers. When looking at the separate subscales in a five-year prospective study, only demand and effort were significant predictors of MetS. Furthermore, we found an unexpected positive correlation between the control subscale and some components of MetS, which needs further consideration. In this respect, we want to introduce a model by Carayon and Zijlstra [56]. This model posits different influences on job strain by three dimensions of job control; namely task control, resource control, and organizational control. Control over tasks performed and resources used are considered to negatively influence job strain. Organizational control, however, might show different effects. Organizational control can include group and organizational responsibilities. The term 'active job', by Karasek and Theorell [57], inheres in this category. While people in such positions can delegate tasks, they remain responsible for, and accountable to the success of the outcome. Carayon and Zijlstra [56] argued that work pressure, and hence job strain, would increase with such organizational control. Our results are, therefore, important to highlight for future research. To the best of our knowledge, no study has examined health-related effects of different control dimensions in police officers. Further distinctions might enhance the quality of evidence for the Job Content Questionnaire, as this is one of the most frequently applied job stress questionnaires.

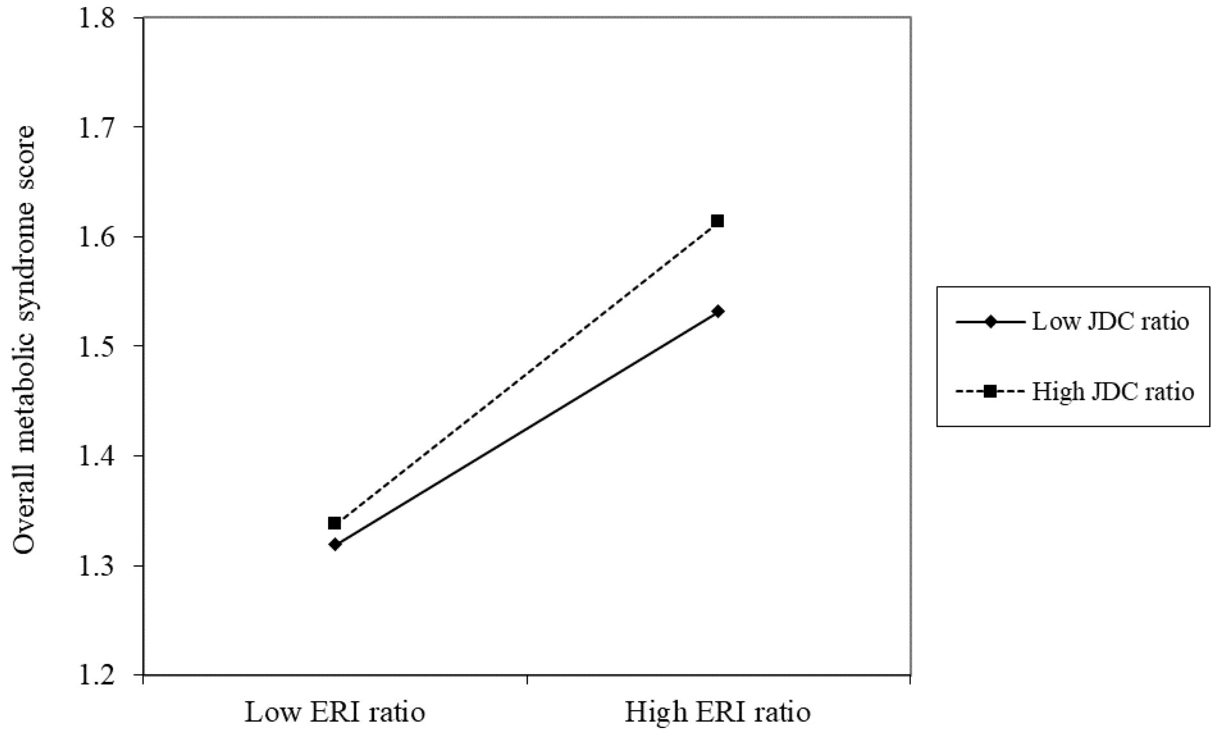

Fig 1. Graphical representation of the interaction between JDC ratio and ERI ratio in predicting overall MetS scores at baseline (n = 82).

https://doi.org/10.1371/journal.pone.0236526.g001

With our second hypothesis, we expected an inverse relationship between physical activity or CF and MetS. Our results fully support this hypothesis for CF, whereas only partial support was found for physical activity. Whereas in the correlational analyses, higher levels of physical activity were associated with more favorable scores in some (but not all) MetS components, no significant association was found between MVPA and the overall MetS score in the regression analyses. In contrast, several previous studies reported relatively strong correlations between physical activity and Type II diabetes, blood pressure, obesity, and lipid levels [58–60]. For the interpretation of our findings, it is important to consider international recommendations for MVPA, such as those of the World Health Organization (WHO) or the American Heart Association [53, 61]. These recommendations highlight that adults should accumulate at least 150 minutes of weekly MVPA. Although higher physical activity levels are considered to be even more health-enhancing, the greatest health benefits are thought to occur in the shift from inactivity to recommended levels [61]. In a Canadian sample which was described as physically active, 23.9 percent of the 2324 participants reached recommended levels of MVPA [62], and the study results yielded strong correlations between MVPA and MetS [62]. Compared to this sample, where only a minority of participants accomplished recommended MVPA standards, our sample was much more active, with 97 percent meeting the recommended minimum of 150 minutes of MVPA per week. Hence, the possible health benefits for increased physical activity levels might be limited (ceiling effect). In line with this notion, some scholars have argued that it is likely to find the strongest relationships between physical activity and MetS in physically inactive and unfit individuals [63]. In summary, we suggest that the high overall physical activity level of our study participants has lowered the potential to detect a significant relationship between MVPA and MetS.

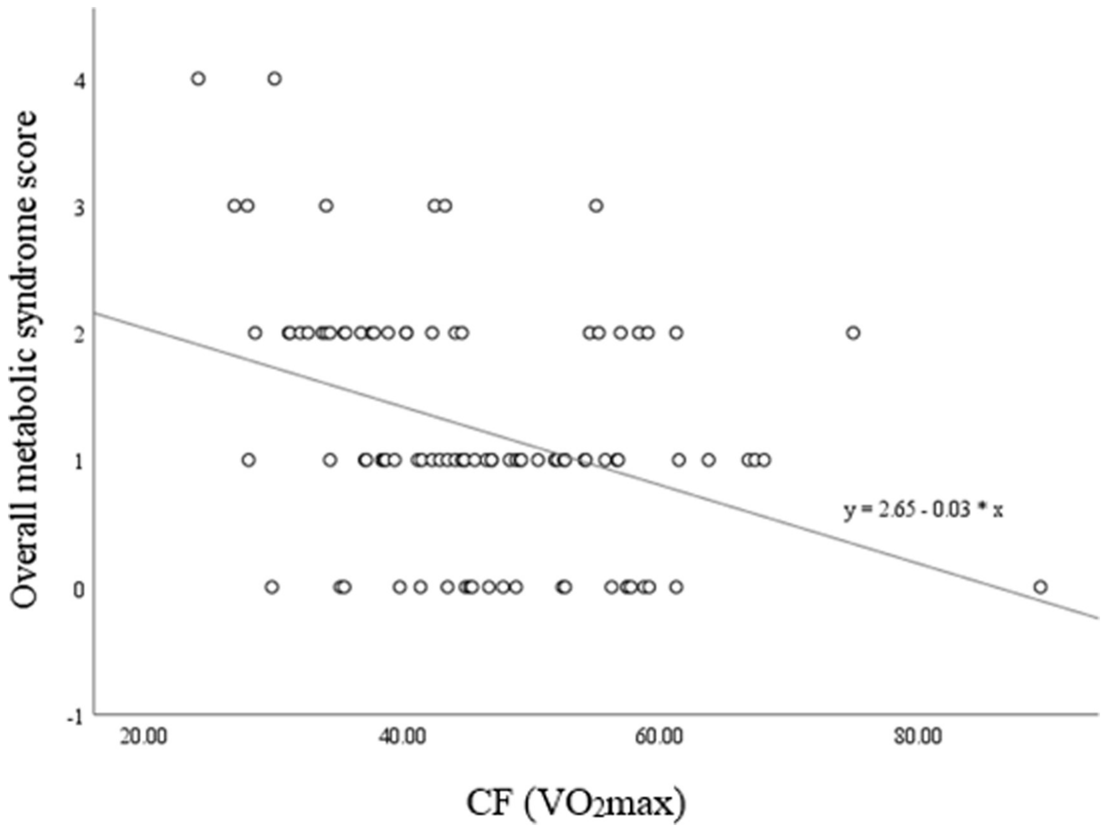

Fig 2. Scatterplot with line of best fit capturing the association between CF (VO_2max) levels and overall MetS scores at follow-up (*n* = 96).

https://doi.org/10.1371/journal.pone.0236526.g002

In spite of this, we found full support for our hypothesis with regard to CF. Throughout all analyses (correlations; regression analyses) higher levels of CF were associated with more favorable scores in almost all of the MetS components. In cross-sectional analyses, only the association between CF and blood sugar and systolic blood pressure did not reach the level of significance. Furthermore, CF significantly predicted the overall MetS score after one year, explaining 9 percent of variance in the final statistical model. This association vividly showed in the group differences based on the ACSM classifications of cardiorespiratory fitness (Fig 3A and 3B). Participants with very poor to poor fitness showed higher overall MetS scores compared to the rest of the sample. This difference appeared more distinct regarding the follow-up values of overall MetS scores. These results are in line with previous evidence from the general population, and the occupation of law enforcement specifically [64, 65]. We also want to emphasize the importance of these results in view of the aforementioned relevance of cardiovascular diseases and mortality, with MetS being suggested as a potential link between work stress and cardiovascular diseases [13].

With our third hypothesis, we expected a moderation effect of physical activity or CF on the relationship between work stress and MetS. This hypothesis seemed plausible as previous investigations mostly supported stress-buffering effects of physical activity and CF [25, 66]. These effects have been ascribed to different physiological pathways including the hypothalamic-pituitary-adrenal (HPA) axis and the sympatho-adrenal medullary (SAM) axis [67]. While MetS is not regarded a proxy of these axes, research has shown a greater interest in

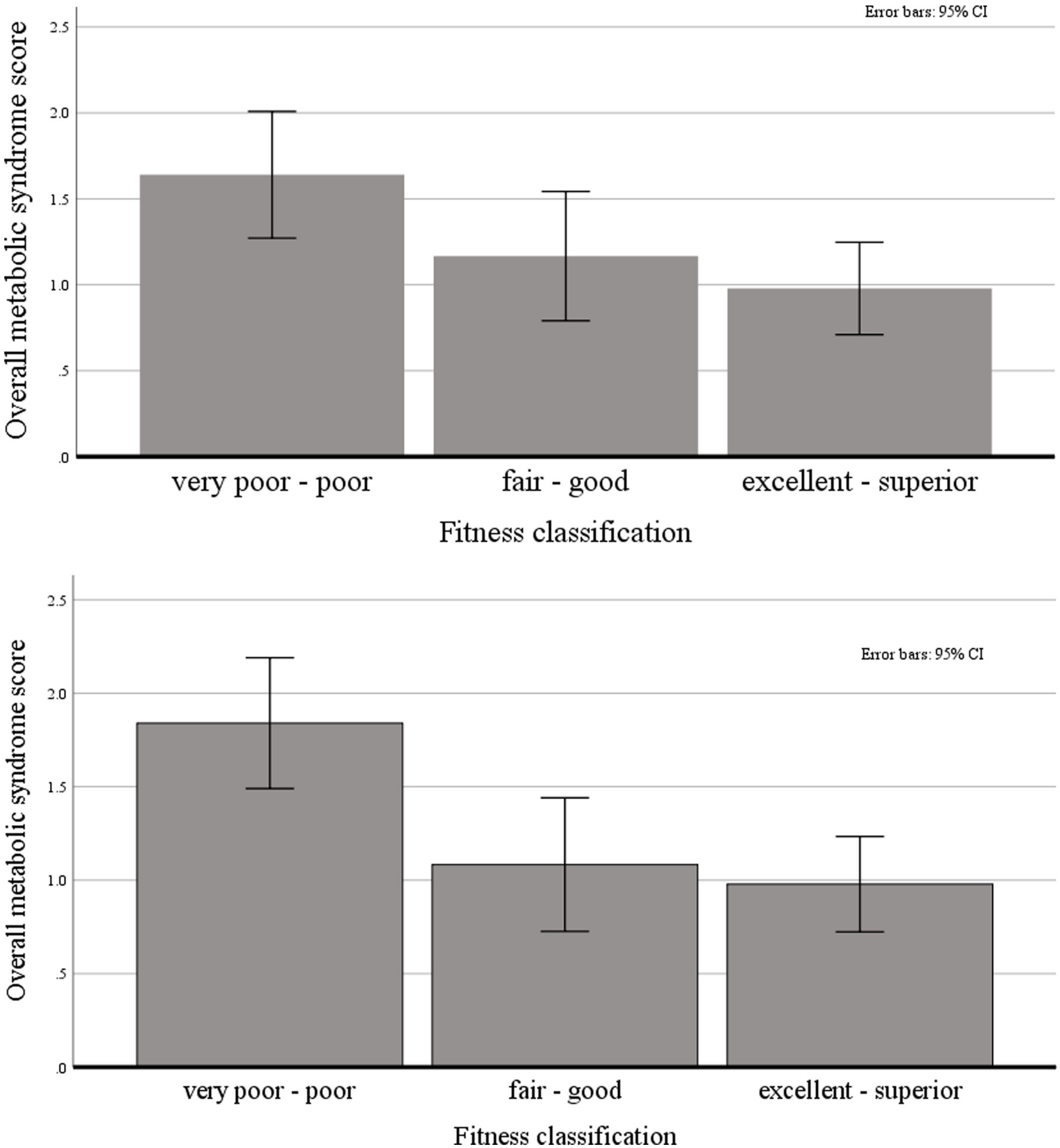

Fig 3. **A.** Bar plot with confidence intervals (95%) regarding the distribution of overall MetS scores at baseline in the different fitness classifications following ASCM guidelines (n = 96). **B.** Bar plot with confidence intervals (95%) regarding the distribution of overall MetS scores at follow-up in the different fitness classifications following ASCM guidelines (n = 96).

https://doi.org/10.1371/journal.pone.0236526.g003

closely related parameters [68]. In this regard, cortisol or further inflammatory risk markers such as C-reactive protein are important factors associated to cardiovascular disease [7, 69]. In line with this notion, Violanti et al. [70] observed a significant shift in the cortisol response in highly stressed police officers. Nevertheless, in a study by Franke et al. [71], work stress (job strain and effort-reward imbalance) did not predict increased inflammatory risk markers in police officers. Moreover, it is also conceivable that psychosocial stress has an impact on health behaviors (e.g. nutrition) which might contribute to the occurrence of MetS [25], including epigenetic or biochemical variations [72, 73]. For example, Charles et al. [74] showed that physical activity significantly interacted with oxidative stress and obesity in a sample of police officers.

Despite these solid theoretical foundations, in the present sample of police officers, the interactions of physical activity and CF with job stress did not significantly predict MetS after one year. Only very few studies have tested stress-buffering effects of physical activity and CF in police officers. Gerber et al. [19] showed that exercise levels and fitness buffered the effects of work stress on health in a sample of Swiss police officers. However, these results relied on self-reports of fitness, exercise, and perceived health. In an earlier study, Young [75] included 412 law enforcement officers. Using a cross-sectional design, Young [75] did not find significant moderation effects of cardiorespiratory fitness in the interplay between stress and risk factors for coronary artery disease. Similarly to our study, Young [75] did not find significant direct associations between job stress and cardiovascular risk factors. Moreover, only few previous studies looked at cardiometabolic risk factors. For instance, in a study with Swedish health-care workers, Gerber et al. [27] observed that higher stress scores were associated with an increased overall cardiometabolic risk. Under these conditions, Gerber et al. [27] showed that participants with high stress who also had high CF levels had lower scores for systolic and diastolic blood pressure, LDL cholesterol, triglycerides and total cardiometabolic risk than participants with high stress but low or moderate CF levels. Similar stress-buffering effects on specific MetS components were found in child and adolescent samples [28]. A recent systematic review described the evidence regarding the association between work stress and cardiovascular risk factors in police officers [76]. Although the association appears to be of a positive nature, Magnavita et al. [76] highlighted the importance of longitudinal studies with large sample sizes in order to find significant effects. Given that work stress did not significantly correlate with components of MetS in the present study, the potential for physical activity and CF to moderate this relationship was limited in the present analysis. Thus, we hold that the lack of significant main effects of job stress might be one of the primary reasons we did not find a stress-buffering effect in the present population.

The strengths of our study are the prospective research design and the fact that objective data was assessed for physical activity (7-day accelerometry), CF (submaximal fitness test) and cardiometabolic risk factors. A lack of objective assessments has recently been identified as one of the key limitations in this area of research [27, 77]. The only self-report variable used in the present study was work stress. However, since stress is personal experience based on cognitive-transactional appraisal processes, it is difficult to find an objective indicator. While potential biomarkers such as hair cortisol are discussed in the literature [78], the validity of such indicators remains questionable in predominantly healthy populations [79, 80]. We have therefore decided to use well-accepted and validated tools to assess job stress, which have been previously employed with police officers [76]. In the assessment of cardiometabolic risk, we followed one of the most widely accepted definitions for MetS. To the best of our knowledge, no study has examined the direct association between objectively assessed physical activity and MetS in police officers.

Despite these strengths, the generalizability of our results might be limited due to several reasons. First, our sample was highly active, and most officers had relatively high CF levels. Furthermore, prevalence of MetS in the present sample was low. While in previous studies with police officers in the United States, prevalence rates for MetS ranged between 16 and 26 percent [17, 24, 32, 33], the prevalence was considerably lower in our sample (7% at baseline, 8% at follow-up). In a review of the literature, Yoo et al. [81] concluded an overall lowered risk for MetS in US police officers compared to the general publication. Although no populations-based data exist for Switzerland, a comparison with 12 cohorts from 10 European countries (N = 34'821 subjects), in which the overall prevalence of MetS was 24.3 percent (23.9% in men, 24.6% in women), shows that the level of MetS was far below average in our study. The prevalence rate found in our study must be interpreted with caution, as participation in the investigation was voluntary. Thus, in the sense of a healthy worker effect, it is likely that more healthy officers were more willing to participate in the study. Furthermore, based on the increased standard error related to the statistical analyses, the present sample size may have been a limiting factor in detecting effects. Finally, the follow-up period (one year) was relatively short in the present investigations, given that most studies finding significant associations between work stress and MetS followed participants across much longer periods of time [14, 55, 82].

Conclusion

MetS is increasing at an alarming rate in industrialized countries. The prevalence rates and close link to cardiovascular disease and mortality have generated a great interest in research of preventive and rehabilitative factors. Although the prevalence of MetS was relatively low in the present sample, our results highlight the importance of CF in the prevention of MetS in highly active and fit individuals. Accordingly, provision of regular training opportunities and repeated CF testing should be considered as a strategy in overall corporate health promotion.

Acknowledgments

We would like to thank all participants of the police corps of the Canton of Basel-City for taking part in our study. We further want to express our gratitude to the management of the police corps for their support and the possibility to use police internal infrastructures throughout the entire study. In this respect, all employees involved in the recruitment, administration, and facilitation processes deserve special thanks for their essential efforts in implementing the study. Finally yet importantly, we thank the master students Benjamin Grossmann and Nico Güdel for their contribution to the data assessment. The research endeavor complies with the current laws of the country in which they were performed.

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Software: René Schilling, Markus Gerber.

Supervision: Markus Gerber.

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Visualization: René Schilling, Flora Colledge, Markus Gerber.

Writing – original draft: René Schilling, Flora Colledge, Markus Gerber.

Writing – review & editing: René Schilling, Flora Colledge, Uwe Pühse, Markus Gerber.

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3.5 Publication 5: Real-life analysis on the cross-stressor adaptation hypothesis

Title:

Does cardiorespiratory fitness buffer stress reactivity and stress recovery in police officers? A real-life study.

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Published in:

Frontiers in Psychiatry, 2020, 11(594).

Publication available at:

https://doi.org/10.3389/fpsyt.2020.00594 frontiers in Psychiatry

ORIGINAL RESEARCH
published: 23 June 2020
doi: 10.3389/fpsyt.2020.00594

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Does Cardiorespiratory Fitness Buffer Stress Reactivity and Stress Recovery in Police Officers? A Real-Life Study

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OPEN ACCESS

Edited by:
Claas Lahmann,
Medical Center, University of Freiburg,
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Reviewed by:
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Yale School of Medicine,
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Specialty section:
This article was submitted to
Psychological Therapies,
a section of the journal
Frontiers in Psychiatry

Received: 06 November 2019
Accepted: 09 June 2020
Published: 23 June 2020

Citation:
Schilling R, Herrmann C, Ludyga S,
Colledge F, Brand S, Pühse U and
Gerber M (2020) Does
Cardiorespiratory Fitness Buffer Stress
Reactivity and Stress Recovery in
Police Officers? A Real-Life Study.
Front. Psychiatry 11:594.
doi: 10.3389/fpsyt.2020.00594

High levels of cardiorespiratory fitness have the potential to buffer against physical and mental health impairments, which can result from exposure to occupational stress. Police officers are especially at risk of high psychosocial stress; therefore, effective intervention strategies are warranted. Given this background, the purpose of the present study was to examine whether police officers with different levels of cardiorespiratory fitness differ with regard to their (a) physiological stress reactivity during acute real-life stress situations, and (b) physiological recovery related to acute and chronic work stress. In total, 201 police officers took part in this study (M = 38.6 years, SD = 10.1, 35.8% females). Officers were contacted eight times on a smartphone during their workday, and asked to report their current level of positive and negative affect, as well as feelings of stress and anger. Physiological stress responses and recovery (heart rate variability) were assessed using Movisens EcgMove3 devices. The Åstrand bicycle ergometer test was used to assess participants' cardiorespiratory fitness. Chronic work stress was assessed using the effort-reward imbalance model and the job strain model. Multilevel modeling was used to test buffering effects of cardiorespiratory fitness on physiological stress reactivity. Linear regression was applied to test stress-buffering effects of cardiorespiratory fitness on physiological recovery. Results showed lowered physiological stress reactivity to acute work stress in officers with higher levels of cardiorespiratory fitness. However, these results were not consistent, with no effects occurring for feelings of anger, positive affect, and negative affect. Chronic work stress (effort-reward imbalance) was related to lower physiological recovery. Cardiorespiratory fitness was positively related to physiological recovery. Data did not support interactions between work stress and cardiorespiratory fitness on physiological recovery. To some extent, cardiorespiratory fitness seems to have the potential to buffer stress reactivity in police officers in acute stress situations. Therefore, we encourage promoting fitness programs which aim to enhance cardiorespiratory fitness in stressful occupations such as law enforcement.

Improvements in cardiorespiratory fitness might further enhance physiological recovery from chronic work stress, which is thought to improve cardiovascular health.

Keywords: cardiorespiratory fitness, stress-buffer, cross-stressor adaptation, heart rate variability, occupational stress, stress reactivity, stress recovery, ecological momentary assessment, ambulatory assessment

INTRODUCTION

Psychosocial stress is ubiquitous in modern society (1). Although not regarded as negative *per se*, health complaints can occur when individual's coping capacities are exceeded. Documented links between psychosocial stress and health impairments range from physical (e.g. cardiorespiratory) and mental diseases (e.g. burnout) to all-cause mortality (2, 3). Consequently, the individual and societal burden is tremendous (4); hence, health services and researchers are keen to find ways to strengthen coping abilities (5).

Conceptualizations for pathways linking stress to health have historically developed from response (biopsychological) and stimulus (stressor) approaches to transactional processes, in which perceptions of stress play a key role (6). Berntson and Cacioppo (7) argue that mechanisms of stress which affect health involve at least four process components: exposure, reactivity, recovery, and restoration. Exposure is understood as a quantitative representation of perceived stressors. Reactivity refers to the strength of a (physiological) stress reaction in relation to a baseline value. This could be an elevated heart rate following a stress event. Recovery is understood the amount of time required until an individual has returned to baseline level following a stress reaction. Restoration, a more unique concept, refers to "anabolic processes that refresh or repair the organism, because stress may directly impede our ability to perform these functions (e.g., disturbed sleep and impaired wound healing)" (p. 609).

Cardiorespiratory fitness (CF) is understood as a potential buffer in the interplay between stress and health. In their review, Gerber and Pühse (8) gleaned evidence on positive moderation effects for exercise and resulting CF on the interplay between stress and health. Mechanisms of improved cardiovascular health are thought to relate to changes in the autonomic nervous system (8). The sympathetic and parasympathetic nervous system are main components in the sympathoadrenal-medullary (SAM) axis. In stressful situations, the SAM axis pathways increase heart rate, breathing pattern, and blood pressure (9). Recurring and excessive activity of the SAM contributes to increased cardiovascular risk, for example, by increasing the likelihood of hypertension (10). Findings further suggest that physical strain produced by regular engagement in exercise and improved physical fitness are associated with adaptations (i.e. lowered resting heart rate and blood pressure) that may counteract the negative consequences of stress. Furthermore, the cross-stressor adaptation hypothesis (11) suggests that repeated exposure to physical strain can result in at least partially unspecific adaptations, which may cross over to other areas of stress (e.g., psychosocial), and thus lead to more favorable adaptations associated with stress (12).

Research on stress-buffering mechanisms to enhance health has mainly focused on stress reactivity and recovery (2, 8). Previous investigations generally support stress-buffering effects associated with CF (13). However, evidence from three meta-analyses on the impact of CF on cardiovascular reactivity and recovery during and after exposure to experimentally induced stressor tasks have provided heterogeneous results (14–16). In their early work, Crews and Landers (14) showed that CF was associated with a blunted stress reactivity. Twenty years later, Forcier et al. (15) came to a similar conclusion when using more strict inclusion criteria. Thus, their meta-analysis found improved reactivity and some support for improved cardiovascular recovery among individuals with higher CF levels. Controversially, in a further meta-analysis, Jackson and Dishman (16) did not find support for an attenuated stress reactivity among fitter individuals. However, higher fitness levels were associated with a slightly better cardiovascular recovery from laboratory stressors. One strength of their results is the inclusion of studies using submaximal or maximal fitness tests, which, according to the American College of Sports Medicine (17), is a prerequisite for a valid determination of CF. Furthermore, in a recent systematic literature review, Mücke et al. (12) gathered evidence on the influence of CF on stress reactivity in response to the Trier Social Stress Test (TSST), a psychosocial laboratory stressor that has proven to elicit particularly strong stress reactions in previous studies (18). Approximately half of the studies included in this review showed that higher levels of fitness were related to attenuated stress reactivity, as measured *via* heart rate variability and salivary cortisol concentrations (12).

One possible explanation for the inconsistent results in the afore-mentioned meta-analyses might be seen in the diversity of stressors used in the laboratory (19). Artificial stressors are sometimes passive physical performance tasks (holding the hand in a bucket of ice water), and oftentimes consist of cognitive instead of psychosocial challenges. Furthermore, when measuring stress in a laboratory setting, even psychosocial stressors might not be personally relevant (20). Additionally, such stressors are mostly isolated events which are typically short-term, whereas the effects of long-term psychosocial stress are more important from a health perspective. Accordingly, due to limited external validity, results obtained in laboratory settings might not be generalizable to a real-life context. Scholars have therefore emphasized that more meaningful insights should be gained in research carried out in more naturalistic environments (20, 21).

Stress experiences at work are very common in adults (5). Two of the most recognized theoretical models in research on work stress are the effort-reward imbalance (ERI) model, which assumes that stress is the consequence of an imbalance between perceived efforts and rewards at work, as well as the job demands and control (JDC) model, which states that stress occurs if perceived demands and control at work are outbalanced (22, 23). Kivimäki, Virtanen, Elovainio, Kouvonen, Vaananen, and Vahtera (24) showed that in both models increased stress is related to higher cardiovascular mortality. In a retrospective study, the authors examined approximately 800 (mainly male) workers in the metal industry, with an average follow-up time of 25 years. Mortality risk ratios increased to 2.4 (95% CI: 1.3, 4.4) for high ERI, and 2.2 (95% CI: 1.2, 4.2) for high job strain (JDC imbalance), respectively. Furthermore, the risk associated with higher stress levels decreased by 30% in the intermediately physically active group, and by 60% in the highly physically active group.

In order to assess physiological stress reactivity and recovery objectively in real-life, heart rate variability (HRV) has become a popular and frequently used parameter in stress research (25). HRV refers to fluctuations in time intervals of successive heart beats (N-N intervals), measured in milliseconds. These differences can be attributed to branches of the aforementioned SAM axis (sympathetic and parasympathetic nervous system) (26). The Root Mean Squares of Successive N-N Differences (RMSSD), a measure of parasympathetic activity, is used frequently as an indicator of physiological stress reactivity and recovery in real-life measurements (27). Studies assess HRV-based physiological reactivity as hourly (28) and daily (29) aggregations of HRV values, or as the differences between day and night HRV values (29, 30). HRV-based physiological recovery is often assessed as aggregated night HRV levels (28, 29, 31), as well as balance indices between day and night HRV (32). Existing evidence suggests that stress-related differences in HRV are significantly associated with cardiovascular disease (33) and mortality (34).

In their review, Tonello, Rodrigues, Souza, Campbell, Leicht, and Boullosa (35) reported strong negative correlations between work stress and HRV. However, the authors stated that optimal methods for detecting adaptations related to cardiac autonomous stress *via* HRV still need to be developed. A more recent review by Järvelin-Pasanen et al. (27) on work stress and HRV corroborated the general results of Tonello et al. (35), and added more detailed information on the specific HRV parameters that were evidently influenced by chronic and acute work stress. Vrijkotte et al. (32), for example, assessed chronic and acute work stress in a sample of 109 male white-collar workers, which were followed-up for two consecutive workdays. Stress levels were matched to RMSSD, as a HRV parameter reflecting vagal tone. The high ERI group showed lower RMSSD, pointing towards decreased parasympathetic activity in individuals with higher chronic work stress. Work stress of the current day was assessed using the Profile of Mood States (assessed in the evening, retrospectively for the day). Although ERI scores were associated with negative mood states, no significant relationships were observed between mood states and HRV (32). Finally, the randomized controlled trial by von Haaren et al. (28) for the first time points towards the stress-buffering potential of increased CF when objective stress markers are assessed in a real-life context. More specifically, in a sample of 61 sedentary university students, an increase in CF after a standardized physical activity (PA) intervention was associated with higher RMSSD (β = 0.15) during a period of heightened academic stress (exam period).

The existing literature on real-life stress is often based on cross-sectional designs, with single work stress scores or aggregated HRV-values, respectively. Järvelin-Pasanen et al. (27) explicitly highlighted the lack of longitudinal studies. However, studies with longitudinal designs are important for at least two reasons: First, single chronic stress scores or aggregated mean levels in outcomes might show different associations than multiple acute stress perceptions/responses (36). Second, the individual evaluation of the predictability and controllability of stressors is fundamental for the reaction to them (37). Nevertheless, these intra-individual differences are not sufficiently accounted for by inter-individual study designs. In order to highlight differences between situations that are considered highly stressful *versus* not stressful, participants have to function as their own controls. Hence, studies with within-subject designs become necessary (38).

While traditional methods have applied retrospective self-reports, technological improvements enable real-life measurements *via* ecological momentary assessment (EMA). Using portable devices, experiences can be assessed in real-time, rather than necessitating long-term recall (39). Consequently, stress research has experienced a growing interest in state variables, such as emotional reactions and changing mood states (40). Emotions and mood states are understood as cognitively mediated psychophysiological reactions that are limited in time (40). Emotions (i.e. anger, fear) are situational and intense, whereas mood states are longer-lasting, rather unspecific background phenomena, and not consistently cued by specific events (40).

In an ambulatory research study with 73 teachers (M = 46.7 years, SD = 9.5; 67% male), Pieper, Brosschot, van der Leeden, and Thayer (41) showed independent associations of stressful events and worry episodes with lowered HRV (measured as RMSSD). Uusitalo, Mets, Martinmaki, Mauno, Kinnunen, and Rusko (42) examined the relationship between emotions (stress, irritation, satisfaction) during two workdays using mean values of emotions and HRV in a sample of 19 hospital workers. A strong negative correlation between feelings of stress during work and RMSSD (r = −0.70 to r = −0.80) indicated lowered parasympathetic activity in an acute stress response. Similarly, chronic work stress, measured as imbalance between efforts and rewards, was strongly related to RMSSD (r = −0.53).

Taken together, there is still a marked lack of research addressing the stress-buffering effect of CF in real-life contexts. Therefore, the purpose of the present study is to examine whether police officers with different levels of CF differ with regard to their (a) physiological stress reactivity during acute real-life stress situations, and (b) physiological recovery related to acute and chronic work stress. Based on the aforementioned literature, two hypotheses were tested:

- With the first hypothesis, we expected individuals to show a greater physiological stress reactivity (decrease in HRV) in acute work stress situations with lower group levels of CF (28).
- With the second hypothesis, we expected improved physiological recovery (increased HRV) in groups with higher levels of CF when exposed to acute and chronic work stress situations (30).

MATERIALS AND PROCEDURES

Participants

Participants were recruited from the police force of the canton Basel-Stadt, a German-speaking city in Switzerland. All employees were invited to participate *via* intranet, internal newspaper, internal TV-adverts, and during team meetings. The present data is part of a voluntary health-check in a bigger project (HERO-study). Additionally, a lifestyle coaching and a second health check were offered to interested officers. Data presented in this article are based on the first health check, which took place between October 2017 and March 2018. Following the invitation, officers had the opportunity to use an e-learning tool, consisting of short text modules and video sequences, in which the general purpose and procedures of the study were explained. Furthermore, information was provided regarding the voluntary nature of participation, the absence of negative consequences in case of non-participation, benefits and risks, rights and obligations, as well as detailed information about the measurements. No monetary incentives were provided to the officers. However, the health check was performed during (paid) working hours and participants received a personalized health profile. At the end of the e-learning phase, participants had the possibility to schedule their own assessment. To participate in the submaximal CF test, participants had to pass a PA readiness check, based on the Physical Activity Readiness Questionnaire (PAR-Q) (43). Participants who did not pass the PAR-Q had to provide a doctor's certificate, attesting that the treating doctor considers it safe for the participant to participate in a submaximal fitness test.

The Basel-Stadt police force consists of approximately 1,000 officers. From these, 227 agreed to obtain more detailed information *via* the e-learning tool (approx. 23%), and 201 officers decided to participate in the study (88%). All participants provided written informed consent prior to data assessment. All procedures followed the ethical principles of the Declaration of Helsinki. The Ethics Committee for Northwest/Central Switzerland approved the study (EKNZ: Project-ID: 2017-01477).

Procedures

Data used in the present paper was acquired during the laboratory session and in real-life. The laboratory session took place at the education and training center of the police force; all tests were performed in a private setting in the same specially equipped room. All assessments were carried out by the same investigator. In real-life, heart rate was monitored for 48 h. To ensure the assessment of full (daytime) working days among shift-workers, the real-life assessment started on their first day of a shift cycle. By contrast, among participants with regular office shifts, the real-life assessment started on a day before two full working days (usually Monday, Tuesday, or Wednesday). To ensure comparability, we analyzed the full workday, following the first night. Furthermore, this procedure may have served to limit low stress measurements, since participants might have scheduled the laboratory session (health check) on days with relatively low workload. At the end of the laboratory session, participants received the sensors and smartphones, as well as oral and written instructions regarding smartphone usage. The real-life measurement started immediately after the laboratory session. Participants wore the heart rate monitor for 48 h consecutively, and answered questions regarding their stress emotions and affect states on a smartphone (see *Measures* section for more specific information).

Measures

Cardiorespiratory Fitness

Cardiorespiratory fitness (CF) was measured with the validated and internationally applied Åstrand Fitness Test (44). In a submaximal performance test on a bicycle ergometer, maximal oxygen consumption (VO_2max) is estimated by standardized extrapolations of heart rates at certain resistances (45, 46). Standardized instructions prior to the testing included the avoidance of any strenuous PA for 24 h, as well as heavy meals, and liquids other than water for 3 h. For the test, participants were equipped with a heart rate monitor. Standardized workloads were set for men (150 watts) and women (100 watts). This workload was adjusted to keep the heart rate in the range of 130–160 (bpm) for participants <40 years, and 120–150 (bpm) for participants ≥40 years. Cycling cadence was set at 60 rotations per minute. At the end of each minute, heart rate was noted, and participants stated their perceived exertion on a Borg scale (47). Prior to the test, participants were instructed that perceived exertion should be between 11 to 16 on the Borg scale (below the maximum range) (47). Standardized encouragements were used and participants were controlled for cancelation criteria (17). After 6 min, the test ended if heart rate over the last 2 min did not vary by more than 5 beats per minute. Otherwise, participants were asked to proceed for another minute until this criterion was met. The mean heart rate of the final 2 min was compared against the final stage watts to achieve a gender adjusted VO_2max (ml/kg/min). These values were matched with CF percentiles using age and gender specific norm values presented by the ACSM (17). Following ACSM recommendations, we further classified participants' CF levels as "very poor," "poor," "fair," "good," "excellent," and "superior" (17).

Chronic Work Stress

Chronic work stress was measured at the end of the laboratory session. Hereby, the Effort-Reward Imbalance (ERI) scale (22) and the Job Demand and Control (JDC) scale (48) were administered using an online questionnaire. The ERI scale consists of 5 items for efforts (i.e. "I have a lot of responsibility in my job") and 11 items for rewards (i.e. "I receive the respect I deserve from my superior or a respective relevant person."). Answers are given on a five-point Likert-scale ranging from 1 (none) to 5 (very high). After summing up each dimension, the ratio was calculated using the factor 0.4545 to counterbalance the unequal number of questions (effort/[reward*0.4545]). Ratios above 1 reflect high levels of job stress (22). The JDC scale consists of five items for demands (i.e. "My job requires me to work very fast") and six items for control (i.e. "I have freedom to make decisions about my job"). Answers are given on a four-point Likert-scale ranging from 1 (never) to 4 (often). Sum scores for each dimension were calculated. As for ERI, the JDC-ratio was calculated using the factor 0.8333 to balance the unequal numbers of questions (demands/[control*0.8333]). JDC Ratios >1 indicate high work stress (49). The validity and reliability of this instrument has been described previously (50).

Ecological Momentary Assessment

Psychological variables in real-life were assessed *via* the EMA method. Each time they were contacted, participants answered different sets of questions on a smartphone (Moto G, 3d Generation) *via* Movisens*XS* (movisens GmbH, Karlsruhe, Germany), an app for Android Smartphones. Movisens*XS* offers a web-based software solution for question settings, sampling contingents, and management of participants; at a later stage, the software processes and prepares data output for analysis. Three sets of questions were triggered in the morning, during the workday, and in the evening. The present paper considers the workday set, which will now be described in detail. The workday set sampled between 12 am and 7 pm for all shift workers (matching their shift schedule) and between 9 am and 5 pm for regular office workers. Sets were time-triggered once per hour with a random appearance of +/− 15 min. The participants responded to an alarm (tone and vibration), which otherwise would repeat every 5 min; if participants did not complete the survey after 15 min, the current assessment was closed. Additionally, participants had the opportunity to postpone the first alarm for up to 15 min. In this case, only one further alarm was triggered 15 min later.

Acute Work Stress

In the present study, acute work stress is used as an umbrella term for affective states, as well as feelings of stress, and feelings of anger. The term "feelings of stress" is specifically used for the acute feeling of being stressed, as a single variable only. Approximately 2 min were needed to answer an entire set of questions. Instructions on how to respond to questions associated with the assessment of acute work stress were given during the laboratory session. More specifically, participants were asked to refer to the current situation right before the assessment when answering questions on affect states, feelings of stress, and anger. Since psychological variables were linked to HRV, we controlled for PA as a possible confounder, using two control questions: "Have you been physically active during the past 15 minutes?" and "Have you been physically inactive during the past 15 minutes?" For these questions, participants were instructed to ignore very short walks and standing periods.

Positive and negative affect states were assessed using an adapted German version of the Positive And Negative Affect Schedule (PANAS) (51). Validity of this instrument has been presented previously (52). Participants were asked how they feel at the moment. The items were reflective of five positive (i.e. "content," "delighted") and five negative affect states (i.e. "irritable," "hostile"). Items were answered on a five-point Likert scale, ranging from 1 (not at all) to 5 (very).

Feelings of stress was assessed with a single item: "How stressed do you feel at the moment?" Answers are given on a five-point Likert scale from 1 (not at all) to 5 (very). Validity of single items for the assessment of stress symptoms has been provided previously (53). "Feelings of anger" was assessed with the item "How angry did you get during the last 10 minutes?" Again, items were answered on a five-point Likert scale, ranging from 1 (not at all) to 5 (very).

Ambulatory Assessment

Heart rate was assessed using ecgMove3 (movisens GmbH, Karlsruhe, Germany). This sensor records a full one-channel ECG waveform (1024 Hz), 3-dimensional acceleration (63 Hz), and barometric altitude (8 Hz) as raw data on internal memory. Evidence about validity and reliability to accurately capture heart rate and PA has been provided previously (54, 55). At the end of the laboratory session, participants were asked to put on the device, which was worn on a textile dry electrode chest belt.

For heart rate variability (HRV) analysis, two HRV subsets were calculated: (i) 10-min HRV (linked to acute work stress during the workday assessed *via* EMA), and (ii) night HRV (following the workday). We applied the same data processing procedure for both subsets. As mentioned above, the full workday and the following night were considered for data analysis. Accordingly, participants became accustomed to the sensors on the first night. In a first step, the *DataAnalyzer* (movisens GmbH, Karlsruhe, Germany) detected sleep periods and non-wear time (56). In a second step, *UnisensViewer* (movisens GmbH, Karlsruhe, Germany), a software for Windows, was applied to view and edit the data. For calculations of HRV subsets, we stored separate files based on tailored sample limits.

Night HRV sample limits were based on accelerometry sleep detection and set between 8 pm and 8 am. Valid night HRV consisted of at least 4 h of detected sleep, with disruption of no more than 10 min. We assessed all participants individually to detect implausible sleep values. Sample limits for 10-min HRV are taken on the complete workdays, between 12 am to 7 pm for shift workers, and 9 am to 5 pm for workers with regular office shifts. Sample limits begin 10 min before the start times of each acute work stress measurement. We calculated raw interbeat intervals using *DataAnalyzer* (movisens GmbH, Karlsruhe, Germany). The interbeat intervals were exported to Kubios version 3.1.0 (57). Automatic threshold based artefact correction was set at 0.15 s (strong) (57). Frequency-domain parameters are based on Fast Fourier Transformation with frequency bands defined in accordance with the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (58). Welch method was used to calculate spectral parameters (segments 300 seconds, 50% window overlap, 5 Hz Sampling frequency). For further analyses, we extracted time-domain parameter RMSSD.

Statistical Analyses

Descriptive statistics (M, SD, Range, Skewness, Kurtosis), group differences in outcome variables (t-test, ANOVA), and correlations (Pearson) of outcome variables (HRV night, HRV of the past 10 mi) and predictors (acute work stress, chronic work stress, CF) were calculated using SPSS 26 (IBM Corporation, Armonk NY, USA). For correlations, within subject variables (level 1) were aggregated over the entire day. Distributions of all variables met standards (skewness <2 and kurtosis <7) recommended for parametric testing (59). Univariate analysis of variance was applied to examine group differences in study variables for different CF levels. Probability levels of $p < 0.05$ were interpreted as statistically significant in all statistical analyses.

Stress Reactivity (First Hypothesis)

To examine stress-buffering effects of CF on physiological stress reactivity in acute work stress situations, multilevel modelling was calculated with HLM 7.03 (Scientific Software International Inc., Lincolnwood, IL) for Windows. We applied two-level random intercept models. All predictor and outcome variables were standardized (z-scores) (60). HRV (RMSSD), which is nested within persons (level 1), was set as an outcome. CF (6 class equivalent) was set as a predictor on the between-person level (level 2). First, acute work stress variables, which are nested within persons (level 1), were included in both levels, with no significant relations occurring. We then calculated our hypothesized model with preceding acute work stress as the assumed causal variable (level 1), CF (level 2) as moderator, and HRV (level 1) as outcome. Random variations were allowed for predictors; however, interactions were set as fixed effects for causality assumptions. Outcome variables were controlled for gender, age, body mass index (BMI), shift work status, years of service, and PA status during the past 15 min in separate predictor models respectively. With none of these covariates being related to the outcome, they were removed in favor of a parsimonious model. Missing data on level 2 was deleted listwise during calculation. First, the null model and intraclass correlation (ICC = $\tau_{00}/(\tau_{00}+\sigma^2)$ was calculated for the outcome variable (10-min RMSSD). Second, each predictor variable (level 1: feelings of stress, feelings of anger, positive affect, negative affect; level 2: CF) was included in a separate model. Third, for the between person predictor CF (level 2), four separate models were calculated, each including one of the four acute work stress variables as within-person predictor (level 1). Reported coefficients (pseudo R^2) refer to estimations with robust standard errors.

Stress Recovery (Second Hypothesis)

To examine stress-buffering effects of CF on physiological stress recovery (night HRV), several (four-stage) regression analyses were performed using SPSS 26 (IBM Corporation, Armonk NY, USA). The first stage included all demographic and social background variables, if they were significantly related to the HRV outcome. In the second stage, we entered occupational stress (chronic work stress as ERI ratio and JDC ratio; feelings of stress). Feelings of stress, originally assessed as a within-subject variable, was now aggregated as mean value over the entire workday. The third stage included CF. The fourth stage included an interaction between CF and each work stress variable. In the fourth stage, centered variables of occupational stress and CF were used. We report stepwise changes in R^2 with the according p-values, and the standardized regression weights with the according *p*-values for each predictor variable in the final model.

RESULTS

Sample Description, Group Differences, and Bivariate Correlations

Descriptive statistics are presented in **Table 1**. Overall, 201 officers participated in the study. Participants stating current use of medication (17 participants) or employment status lower than 50% (11 participants) were excluded from data analysis. The remaining sample consists of 115 men (66.5%), and 58 women (33.5%), mean age 37.64 years (SD = 9.80), mean years at service 12.32 (SD = 8.56). The sample was compared to the entire police corps of Basel-Stadt (N = 980 officers), showing significantly younger mean age (*t*-test compared to 41.88 years: $t(172) = -5.69$, $p < 0.01$), but no significant differences in gender ratio (*t*-test compared to 29.6% women).

Five participants (2.7%) did not answer any acute work stress assessments. Additionally, 13 (7.5%) acute work stress datasets

TABLE 1 | Participants' distribution across the six fitness groups and group characteristics in significantly different variables.

Fitness groups based on ACSM standards	*n*	%	Men	Women	Ratio	BMI (*M* ± *SD*)	Heart rate at night (*M* ± *SD*)
Very poor	30	17.3	27	3	90/10	28.58 ± 4.48	74.34 ± 25.12
Poor	13	7.5	7	6	54/46	25.79 ± 4.11	83.39 ± 29.09
Fair	26	15	20	6	77/23	26.00 ± 3.56	83.99 ± 28.61
Good	28	16.2	18	10	64/36	25.94 ± 2.99	64.95 ± 15.91
Excellent	25	14.5	13	12	52/48	24.66 ± 2.33	73.11 ± 30.11
Superior	51	29.5	30	21	59/41	24.64 ± 2.64	66.56 ± 23.15

ACSM, American College of Sports Medicine; BMI, Body Mass Index.

TABLE 2 | Descriptive statistics for and bivariate correlations between independent and dependent variables.

Variable	Range							Bivariate correlations between the study variables								
	n	*M*	*SD*	Min	Max	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Cardiorespiratory fitness class	173	45.34	11.40	21.90	89.40	0.66	0.71	–								
Chronic work stress																
2. Job Demand Control ratio	162	0.96	0.19	0.54	1.55	0.77	0.46	0.13	–							
3. Effort Reward Imbalance ratio	162	0.89	0.25	0.33	2.02	1.03	2.33	-0.03	0.28**	–						
Acute work stress (aggregated mean values per workday)																
4. Feelings of stress	155	1.70	0.62	1.00	3.86	0.96	0.48	-0.04	0.08	0.28**	–					
5. Feelings of anger	155	1.61	0.52	1.00	3.20	0.77	0.04	-0.03	0.21**	0.20*	0.66**	–				
6. Positive affect	155	16.50	2.57	5.86	23.00	-0.37	1.33	0.00	-0.12	-0.13	-0.34*	-0.15	–			
7. Negative affect	155	7.58	2.38	5.00	15.71	1.13	0.95	0.00	0.13	0.28**	0.74*	0.58**	-0.39**	–		
Heart rate variability																
8. Night RMSSD	156	45.81	17.32	10.60	98.84	0.85	0.60	0.08	0.13	-0.29**	-0.85	0.08	0.04	-0.05	–	
9. 10-min RMSSD	154	34.70	11.05	5.00	75.00	0.24	0.64	0.17*	0.15	-0.02	-0.09	0.01	0.03	-0.03	0.40**	–

RMSSD, Root Mean Squares of Successive N-N Differences.
*$p < 0.01$; **$p < 0.001$.

were missing due to software problems (n = 7, 4.0%) or invalid data on heart rate variability (n = 6, 3.5%). On average, participants answered 6.47 (SD = 1.34) acute work stress measurements (of a possible 8) over the course of the study. Following Lüdtke, Trautwein, Kunter, and Baumert (61), we calculated ICC(1)[1] for within-level and ICC(2)[2] for between-level reliability of the psychometric measures. ICC(1) can be interpreted as the percentage of variance that can be accounted for by differences between persons. ICC(1) values were 0.19 (19%) for anger, 0.45 (45%) for stress, 0.67 (67%) for positive affect, and 0.61 (61%) for negative affect. Applying ICC(1) to the Spearman Brown formula, we calculated ICC(2) to estimate the accuracy of the mean values across all individuals. ICC(2) values were 0.60 (moderate) for anger, 0.84 (good) for stress, 0.93 (excellent) for positive affect, and 0.91 (excellent) for negative affect (62). Missing data in night heart rate parameters occurred for 17 participants (9.8%), whereas five (2.9%) datasets were excluded due to artefacts and in 12 cases (6.9%), sensors did not provide data for unknown reasons.

The overall mean of fitness percentiles for CF was 62.93 (SD = 33.37). The participants' distribution across the six-group classification recommended by the ACSM is described in **Table 1**. Group values and standard deviations are presented for variables in which the groups differed significantly. Significant differences occurred for gender ratio ($F(5,167) = 2.81$, $p < 0.05$), body mass index ($F(5,167) = 6.13$, $p < 0.01$), and heart rate at night ($F(5,150) = 2.45$, $p < 0.05$). No significant between-group differences were found for age, shift work status, years of service, HRV parameters at night, and any acute or chronic work stress variables. Interestingly, the very poor fitness group showed lower levels of heart rate at night compared to the poor and fair fitness group. However, *post-hoc* tests did not reach significance (Tukey, Bonferroni).

The bivariate correlations between the different study variables are presented in **Table 2**. These findings show that CF levels (percentiles) were positively related to the aggregated mean values of HRV during the workday. The two chronic work stress questionnaires (JDC, ERI) were positively correlated with each other. While the JDC ratio was only correlated with the acute work stress measure feelings of anger, the ERI ratio was similarly associated with feelings of stress, feelings of anger, and negative affect. Acute work stress parameters and the JDC ratio were not significantly related to HRV outcomes. By contrast, the ERI ratio was negatively associated with night HRV.

Multilevel Model to Examine Physiological Stress Reactivity (First Hypothesis)

Results of the multilevel modelling are presented in **Table 3**. The intraclass correlation provided evidence for a two-level hierarchical structure, showing that 63% of variance in the outcome can be accounted for by intra-individual variables (RMSSD ICC = 0.63) (63). Results of multilevel models are described for CF and acute work stress (gender, age, BMI, shift work status, years of service, and PA during the past 15 min controlled for in separate models; see *Methods*). In accordance with the hypothesis, a cross-level interaction for CF suggests a moderation effect, with higher levels of RMSSD being predicted by higher levels of CF when participants perceived stronger feelings of stress. On the contrary, no interaction effect occurred for feelings of anger, positive affect, and negative affect. Between-subject differences (level 2) in CF were a significant predictor of 10-min RMSSD during the workday. The direction of the association of feelings of stress, as a within-subject (level 1) predictor, and 10-min RMSSD was negative, but not statistically significant. Surprisingly, 10-min RMSSD during the day was not significantly affected by the acute work stress measures.

Regression Analyses to Examine Physiological Stress Recovery (Second Hypothesis)

The results of the regression analyses are provided in **Table 4**. In all models, age significantly explained night HRV levels, with

[1] $ICC(1) = \tau 2/(\tau 2 + \sigma 2)$
[2] $ICC(2) = k \times ICC(1) / (1 + (k - 1) \times ICC(1)$

TABLE 3 | Estimated effects in multilevel models using restricted maximum likelihood with predictors CF, feelings of anger, positive affect, and negative affect on HRV outcome variable RMSSD over the past 10 min.

Outcome	Null model				Level 2				Level 1				Full model							
													Level 1				Cross-level interaction			
	β	*SE*	*T*	*p*	β	*SE*	*T*	*p*	β	*SE*	*T*	*p*	β	*SE*	*T*	*p*	β	*SE*	*T*	*p*
					Cardiorespiratory fitness class				Feelings of stress								Cardiorespiratory fitness class × feelings of stress			
10-min RMSSD	0.03	0.07	0.52	0.751	0.14	0.07	2.00	0.045	-0.02	0.03	-0.51	0.437	-0.03	0.03	-1.02	0.324	0.06	0.03	2.04	0.043
									Feelings of anger								Cardiorespiratory fitness class × feelings of anger			
									-0.02	0.02	-0.69	0.407	-0.02	0.02	-0.69	0.433	-0.00	0.03	-0.69	0.372
									Positive affect								Cardiorespiratory fitness class × positive affect			
									-0.06	0.04	-1.34	0.357	-0.06	0.04	-1.34	0.397	-0.01	0.05	-0.15	0.469
									Negative affect								Cardiorespiratory fitness class × negative affect			
									0.03	0.03	0.83	0.395	0.03	0.03	0.83	0.375	-0.00	0.03	-0.00	0.148

RMSSD, Root Mean Squares of Successive N-N Differences.

TABLE 4 | Linear regression analyses predicting night RMSSD with occupational stress and cardiorespiratory fitness.

	ΔR^2	β	*p*	ΔR^2	β	*p*	ΔR^2	β	*p*
Step 1	0.29		0.000	0.29		0.000	0.31		0.000
Years of service		-0.01	0.905		-0.01	0.905		-0.01	0.947
Age		-0.51	0.000		-0.51	0.000		-0.52	0.000
Shift work		-0.05	0.553		-0.05	0.553		-0.07	0.381
Step 2	0.00		0.384	0.02		0.048	0.00		0.872
Occupational stress									
JDC ratio		0.07	0.384						
ERI ratio					-0.14	0.048			
Feelings of stress								0.00	0.872
Step 3	0.02			0.02		0.006	0.03		0.002
Cardiorespiratory fitness class		0.12	0.006		0.12	0.006		0.17	0.002
Step 4	0.00		0.839	0.00		0.902	0.01		0.092
Occupational stress × cardiorespiratory fitness class		-0.04	0.839		0.01	0.902		0.11	0.092

JDC, Job Demand Control; ERI, Effort Reward Imbalance; RMSSD, Root Mean Squares of Successive N-N Differences.

lower levels of HRV in older individuals. ERI significantly explained variance in night RMSSD. The JDC ratio and feelings of stress did not significantly predict night HRV. CF significantly explained variance in participants' night RMSSD levels, after controlling for feelings of stress. Finally, the interaction terms did not significantly account for variance in the outcomes in any of the calculated models.

DISCUSSION

The aim of the present study was to examine the stress-buffering effects of cardiorespiratory fitness (CF) under realistic conditions. CF significantly moderated physiological stress reactivity (in RMSSD) when participants perceived elevated feelings of stress at work, with higher levels of CF predicting higher levels of parasympathetic activity. However, no direct effects occurred for perceived feelings of stress, feelings of anger, positive affect, or negative affect. Interestingly, the physiological stress reactivity was not significantly affected by acute psychological work stress. Chronic work stress, measured as effort reward imbalance (ERI), was negatively related to physiological recovery at night. While CF was associated with increased physiological recovery at night, no effects on recovery appeared for interactions between CF with chronic and acute work stress. The present pattern of results adds to the current literature in an important way, as one of the first real-life studies examining stress-buffering effects of CF in police officers. With these results, we add distinct insights into the influence emotional and affective states. Our results are novel, because the study design and statistical analysis further accounts for intra-individual differences in the stress response.

With our first hypothesis, we expected stress-buffering effects of CF on HRV in acute work stress situations. CF showed the expected effect when feelings of stress increased, with lower physiological stress reactivity (higher parasympathetic activity) in more fit individuals. The present results corroborate previously proposed stress-buffering effects of CF on cardiovascular stress reactivity (12, 15, 28). However, these results only appeared for feelings of stress, whereas no effects appeared for feelings of anger, and affective states. Since affective states are understood to be less cognitively presented in stress perception, emotions might be more closely related to acute work stress (40). The missing effects for feelings of anger might be related to individual differences in adaptive pathways in the regulation of the stress response (64). As mentioned in the introduction, cognitive processes are key ingredients in the emergence of stress. Anger is linked to a cognitive appraisal (65) of causality and responsibility (66), for example when another person is (perceived to be) responsible for an event with negative consequences for oneself (66, 67). This accountability can discriminate anger from other emotions, such as fear or anxiety, when attributions are not possible (67, 68). Thus, stress can even predispose an individual towards anger (65). However, accountability is, by definition, related to higher perceived controllability and predictability of events, which are key factors in the stress process (37). In line with this, Wu, Gu, Yang, and Luo (69) showed that anger was associated with a higher HRV (higher parasympathetic activity) compared with fear. Consequently, a relatively low reactivity to anger, compared to other emotions, would result in weaker associations, in line with the anticipated buffering effects of CF. In sum, theoretical assumptions and evidence regarding ANS reactions encourage a differentiated, nuanced contemplation of the emotions referred to here (70, 71). Furthermore, no direct effects of acute work stress appeared on HRV. This result is somewhat counterintuitive. In their systematic review, Jarczok et al. (72) showed that adverse psychosocial work conditions were associated with lowered HRV. However, in a 3-day EMA study by Kamarck, Muldoon, Shiffman, Sutton-Tyrrell, Gwaltney, and Janicki (73), the association between demands and physiological parameters reflecting cardiovascular health was not limited to the workplace. Further research is needed to further examine the influence of psychosocial stress during leisure time.

While the present sample represented the overall gender ratio in the police corps, it was also significantly younger. Due to some promising results in older populations (32, 74), our findings might understate possible relevant health effects. Furthermore, police officers have to take physical examinations in the early stages of their career; hence, relatively high CF levels can be expected among study participants. As a consequence, the detected effects of CF as a stress-buffer might be rather conservative in the present study.

With our second hypothesis, we expected improved stress-related physiological recovery patterns (increased parasympathetic activity in high stress levels) with higher levels of CF. Although chronic work stress (ERI) showed negative associations with night HRV, no support of stress-buffering effects appeared for CF. However, CF predicted improved physiological recovery for night RMSSD. Interestingly, chronic work stress measured *via* the JDC ratio, and acute work stress, were not related to night HRV. These results are partly in line with the findings of two reviews (27, 75). Loerbroks et al. (75) found significant age-related partial correlations with ERI and HRV, but not JDC in the age group of 35 to 44 years. The review of Järvelin-Pasanen et al. (27) contained five studies assessing RMSSD. Of these studies, two studies unanimously reported lower RMSSD levels in stressed individuals. However, two studies only found partial support, whereas in one study no significant effect of chronic work stress on RMSSD was detected (76). Interestingly, in the real-life study by von Haaren et al. (28), the control group showed lower levels of night RMSSD during the examination period, compared to the intervention group. These previous results support the present finding, that chronic work stress is associated with reduced physiological recovery processes, measured as HRV.

One explanation for these results might be related to the components of the stress-health relationship (7). As mentioned previously, research on stress-buffering effects of CF mainly focus on physiological stress reactivity and recovery. Nevertheless, with the present paper, we want to encourage researchers to place a stronger focus on restoration processes in future investigations. The descriptions by Berntson and Cacioppo (7) indicate that CF might be related to improved cardiac vagal activity (parasympathetic influence on cardiovascular stress reactivity and recovery) due to anabolic processes. These adaptations might be rather long-term, hence, health-related improvements might be less affected by short-term changes in stress levels. The present study supports this notion, since chronic work stress levels showed more consistent associations with favorable HRV patterns than acute work stress. Interestingly, CF levels did not consequently predict night HRV in all models, whereas mean levels of heart rate at night differed significantly between CF groups. Hence, CF might have different influences on heart rate and HRV (8, 77). These differences are important to understand, since high heart rate and low HRV have been shown to be independent risk factors for cardiovascular disease (33, 41, 78).

Strengths

One of the key strengths of this study is constituted by the methodological advancements in relation to previous research. With the application of real-time assessments of stress reactivity, and with the co-assessment of physiological and psychological parameters, we tackled several gaps in previous research. For instance, using EMA techniques has the potential to minimize bias related to recall times, which constitutes a huge improvement in allowing the examination of the "experiencing self" in contrast to the "reflecting self" (79). Furthermore, our statistical analyses took into account the individuality of the stress-health relationship by statistically accounting for intra-individual changes in stress perceptions and reactions. A further strength of our study is the improved quality of night HRV assessment by including an additional night of acclimatization. Additionally, the present results are based on a rigorous assessment of study variables, with standardized, reliable, and valid tools that are widely applied in international research. The homogeneity of the present sample further allows cohort-specific interpretations in a highly stressful occupation.

Limitations

However, some limitations may affect the generalizability of our data. First, we tested stress reactivity and recovery independently. However, some scholars suggest that these phenomena are interdependent. The "*DynAffect*" model by Kuppens, Oravecz, and Tuerlinckx (80) states that stress responses are dynamic, fluctuating around an individual's emotional "home base." In this sense, reactivity and recovery are understood as the sensitivity to withdraw from, and the attractor strength that ties back to, the home base (80). Furthermore, Smyth, Sliwinski, Zawadzki, Scott, Conroy, Lanza (81) recently introduced their stress response assay that comprises both stress reactivity and recovery. The assay additionally captures pile-up, which accounts for multiple stress responses within a defined time-period. Second, controlling for extraneous variables was not feasible, given the nature of our study design. However, using real-life stressors increases the ecological validity of our findings. Third, although HRV assessments followed the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (58), breathing patterns and physical activity were not controlled for objectively. To improve the quality of subjective physical activity reports, all participants received verbal and written instructions prior to the assessments. Fourth, our results might include errors due to multiple testing on the same dataset. With regards to the associated effect sizes and p-values, our results must be interpreted with caution. In this respect, future observations in police officers may benefit from larger sample sizes.

Practical Implications

Occupational stress among police officers may have a more direct impact on society than that of other occupations, since job performance is closely linked to public safety (82). However, police officers have been shown to be at risk for maladaptive coping strategies (83). Associated organizational costs are considerable due to reduced productivity, absence, and early retirement (84). In this respect, self-regulatory processes to manage emotions and sustain resilience are highly important (85). Self-regulatory techniques primarily aim for an efficient systemic recalibration to physiological and psychological balance after intense stress experiences (85). Furthermore, successful recovery from stress is associated with more favorable physiological stress markers, i.e. cortisol, which is evidently linked to improved functioning of higher-order cognitive tasks. Optimal brain functioning has been related to enhancements in concentration, planning abilities, memory, decision making, moral reasoning, inhibition of inappropriate responses, and inhibition of distractions (85).

Applying HRV biofeedback to successfully enhance coping is well-documented (86). Firstly, monitoring the physiological stress reaction could increase self-awareness of stress experiences (86). Secondly, specific techniques which enhance the regulation of physiological function can be learned (86). These improvements in the physiological stress reaction can complement further psychological self-regulatory techniques (85). In the present results, partial support appeared for CF as a physiological resilience factor, helpful for managing stress in police officers.

Hence, one potential way for police health authorities to enhance self-awareness is to encourage employees to monitor day and night values of HRV. We further emphasize the importance of interventions that focus on improved CF. The present results have shown the association of increased fitness and several known risk markers of cardiovascular health.

CONCLUSION

Our results showed partial support for the potential of CF to buffer cardiovascular reactivity when police officers are exposed to acute work-related stress. Higher levels of CF were related to enhanced physiological recovery, which might have further important implications for participants' health. Therefore, we encourage the promotion of fitness programs with the aim of enhancing CF in stressful occupations such as law enforcement. Finally, we encourage the assessment of HRV for the early detection of maladaptive acute physiological stress reactivity, as well as physiological recovery related to chronic work stress.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee for Northwest/Central Switzerland (EKNZ: Project-ID: 2017-01477). The patients/ participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RS, SB, and MG made substantial contributions to conception and design of the study. RS, SL, and MG were responsible for the acquisition of data. RS, CH, and FC were responsible for the analysis and interpretation of data. RS and CH drafted the manuscript. FC, SB, MG, and UP wrote sections of the manuscript. CH, SB, SL, UP, MG, and FC critically reviewed and revised the initial draft. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

4. Discussion

The goal of the present PhD project was to elaborate the stress-buffering effects of PA and CRF in real-life circumstances. In a one-year prospective study with a sample of 201 police officers, exposure to chronic and acute work stress was examined along with physiological and psychological health parameters. PA was assessed over seven consecutive days via accelerometry, substantiated by a recently developed and validated questionnaire (SIMPAQ). CRF was objectively measured with the submaximal Åstrand cycling test. Chronic work stress was observed with two of the most widely applied work stress questionnaires based on the JDC model, as well as the ERI model. Acute work stress was measured using smartphone-based EMA of current stress experiences, whereas physiological responses were captured using AA of HRV. Cardiovascular risk factors (i.e. blood pressure, blood sugar, and blood lipid levels) were assessed in a laboratory setting and psychological health outcomes via online-questionnaire (i.e. burnout, and sleep health).

The first hypothesis suggested moderating effects of PA and CRF on the association between chronic work stress and cardiometabolic as well as mental health. Higher levels of PA and CRF were suggested to be related to improved cardiometabolic and mental health, with stronger effects when levels of chronic work stress were higher. Validation studies were carried out, confirming the suitability of the applied questionnaires assessing PA (SIMPAQ; Publication 1) and burnout (SMB*M*; Publication 2). Hypothesis testing was performed using cross-sectional and prospective analyses. Cross-sectional analyses focused on the associations between chronic work stress and cardiovascular risk factors as well as mental health under the influence of PA (data not shown) and CRF (Publication 3). The prospective data analysis focused on the associations between chronic work stress and MetS under the influence of PA and CRF (Publication 4). The second hypothesis of this research project addressed the CSA hypothesis. Herewith, lower physiological stress reactivity and increased physiological stress recovery were assumed for individuals with higher levels of PA (results not shown), as well as CRF (Publications 5). Physiological stress reactivity was defined as changes in HRV which were matched to the individuals' specific stress experiences. Physiological recovery was investigated by measuring HRV in the following night.

The results yielded no stress-buffering effects of PA. PA was significantly and negatively correlated with MetS after one year. However, in cross-sectional and prospective regression analyses, the association as well as the interaction with chronic work stress, did not reach the level of significance. CRF only partially occurred as a stress-buffer in the cross-sectional analyses with cardiovascular risk factors as outcomes. While CRF was consistently and significantly related to lower levels of cardiovascular risk factors and MetS, no stress-buffering effect occurred on metabolic syndrome in cross-sectional and prospective regression analyses. The investigation of stress reactivity and recovery in real-life yielded no stress-buffering effects of PA (data not shown). CRF was related to a more favorable stress reactivity regarding feelings of stress, whereas no effects occurred for feelings of anger, positive or negative affect. CRF showed significant associations to more favorable day and night HRV. However, CRF did not significantly predict night recovery in the interaction with chronic and acute work stress.

The results will now be discussed in detail. Herewith, the established hypotheses will first be considered for PA, showing the relationship between chronic work stress and health under the influence of PA. This part also includes the results on physiological stress reactivity and stress recovery related to PA. Secondly, the same order will be addressed for CRF, with a focus on the relationship between chronic work stress and health under the influence of CRF, and the discussion of findings on stress reactivity and recovery under the influence of CRF. The results on cardiovascular risk and MetS are discussed together, due to their close relationship. The third part integrates the results on a conceptual level, discussing theoretical frameworks and underlying stress response models. Fourth, strengths and limitations are presented, finally followed by the conclusion and future direction.

4.1 Physical activity

4.1.1 Stress-buffering effects of physical activity

The suggested stress-buffering effects of PA on the association between chronic work stress and cardiometabolic and mental (data not shown) health were not supported by the current results. The interpretation of these results is challenging, given some inconsistencies in previous studies (Gerber & Pühse, 2009).

In a prospective cohort study by Kivimäki et al. (2002), stress-buffering effects were examined on the basis of the ERI and JDC models. In a sample of 812 metal industry workers, cardiovascular mortality risk was assessed after five and ten years. Chronic work stress showed positive associations with cardiovascular mortality. While the hazard ratios for high job strain in inactive smokers increased from 1.89 (0.93 to 3.81, 95% CI) to 2.20 (1.12 to 4.32, 95% CI), these behavioral factors decreased the hazard ratios for high ERI from 2.36 (1.06 to 5.46 95% CI) to 2.18 (1.15 to 4.13, 95% CI) (Kivimäki et al., 2002). The authors did not further reveal differences in smoking and PA. In a meta-analysis, Kivimäki et al. (2013) focused on job strain and physical inactivity in the development of coronary artery disease. Results showed that, after a mean follow-up time of 7.3 years, participants with high job strain showed an increased hazard ratio of 1.32 (1.08 to 1.60, 95% CI) for developing coronary artery disease. If participants with high job strain were physically inactive, the hazard ratio increased to 1.62 (1.20 to 2.18, 95% CI). Some inconsistencies appeared in a study by Nyberg et al. (2013). The authors examined the relationship between job strain and diabetes occurrence in pooled cross-sectional data of 47,045 participants. The authors showed that the relationship between job strain and diabetes was independent of participants' activity levels.

In their review, Gerber and Pühse (2009) generally supported stress-buffering effects of PA. However, support for stress-buffering effects was found in 16 of the included studies, whereas 15 studies did not show significant results. The authors further highlighted that direct effects of exercise on health factors (i.e. diabetes) might influence results as might the indirect effects of exercise on improved fitness. A review by Hamer (2012) found that PA was a stress-buffer in the development of CVD. However, the corresponding effect sizes are described as small to medium and in some cases negligible (Hamer, 2012). The author further concluded, that acute and long-term effects of PA need to be examined to account for possible interactions. Acute effects of PA are closely related to the CSA hypothesis and will, therefore, be discussed in section 4.1.2.

Taken together, stress-buffering effects of PA have been examined in many studies; however, inconsistencies limit these results. Some questions remain unanswered, i.e. whether acute or long-term PA is a stress-buffer (Hamer, 2012), or if PA indirectly affects stress regulatory processes by resulting in increased levels of fitness (Gerber & Pühse, 2009).

4.1.2 Physical activity and cross-stressor adaptations

In accordance with the CSA hypothesis, influences of PA on physiological stress reactivity and recovery were hypothesized; however, current data did not support this presumption (results not shown). This result is in contrast to the proposed benefits of PA and exercise regarding the outcomes that represent stress reactivity of the SAM axis (Forcier et al., 2006; Mücke et al., 2018). For example, Rimmele et al. (2009) applied the Trier Social Stress Test (TSST) in a laboratory study and found significant stress-buffering effects of PA on HRV, with a lowered reactivity in the highly active group. A review by Hamer, Taylor, and Steptoe (2006) analyzed randomized controlled trials examining blood pressure responses to laboratory stressors. The authors concluded a dose-response relationship in support of a potential stress-buffering effect of PA and exercise on sympathetic reactivity in most of the included studies (Hamer et al., 2006). However, studies examining interaction effects of PA and stress in work stress situations are lacking (Tonello et al., 2014). Gerber and Fuchs (2018) stated that results regarding effects of PA on stress-responses are inconsistent, and that studies applying personally relevant real-life stressors are still clearly underrepresented. Support for the CSA hypothesis in a real-life context has been shown in the above mentioned randomized controlled study by von Haaren et al. (2016). The study implemented an exercise intervention in inactive university students. Von Haaren et al. (2016) showed that the inactive control group had significantly higher levels of stress reactivity and lower levels of recovery, measured as night-time HRV, during the examination period. However, these effects might be related to an improved fitness level in the intervention group.

The review by Hamer (2012) suggested that supporting results for stress-buffering effects of regular PA and exercise may relate to multiple acute effects of exercise. These acute effects might be beneficial in a post-exercise period, called post-exercise window. Frequent exercisers show a higher quantity of post-exercise windows; therefore, they may encounter more stressors during time in which they still benefit from acute exercise effects. Furthermore, Hamer (2012) suggested that more frequent exercisers may show longer buffering states, which might be up to 12 hours for individuals exercising three times a week or more. The author further concluded that both acute and long-term effects of PA need to be considered in order to account for possible interactions (Hamer, 2012). It was not possible to examine (multiple) acute and long-term effects of PA based on the present study design; therefore, further research is necessary to answer these questions, which have not been sufficiently addressed in previous research (Gerber & Pühse, 2009; Klaperski, 2018).

The inconsistencies in the current results and remaining questions in previous research on stress-buffering effects of PA, allow for a closer look at the concept of PA. First, an interchangeable use of the terms PA and exercise is noticeable in some of the existing studies on stress-buffering effects of PA (Gerber & Fuchs, 2018; Gerber & Pühse, 2009; Klaperski, 2018). For example, one study termed the assessed stress-buffering variable as physical activity while leisure time exercise was assessed (Rimmele et al., 2009). Another study termed the absence of exercise as physical inactivity (Chandola et al., 2008). However, the generally accepted (Cavill, 2006) definition by Caspersen et al. (1985) states that PA is "any force exerted by skeletal muscles that results in energy expenditure above resting level" (p. 126). As stated by the American College of Sports Medicine (Ferguson, 2014), exercise is a type of PA that consists "of planned, structured, and repetitive bodily movement done to improve and/or maintain one or more components of physical fitness." (p. 2). While these concepts are apparently different, the assessed behavior in stress research is oftentimes exercise; with intervention studies usually influencing (strength or aerobic) exercise behavior in order to obtain (acute) physiological responses or (long-term) improvements of fitness levels (Klaperski, 2018). However, the majority of health benefits related to PA (including exercise) are thought to be achievable through regular PA in general (Pate et al., 1995). Furthermore, long-term PA, especially habitual PA, is regarded as most health enhancing (Ferguson, 2014; Klaperski, 2018; WHO, 2010). Some of the existing studies assessed habitual PA by eliciting participants' behavior during the previous week (Poole et al., 2011) or weekly activity levels in general (Chen, Chen, Martínez, Etnier, & Cheng, 2019; Perchtold-Stefan, Fink, Rominger, Weiss, & Papousek, 2020). However, the assessment of habitual PA might require more complex considerations. In order to stay in the scope of this research project, habit theory will not be considered here (see Ouellette and Wood (1998), as well as Hagger (2018) for further literature). However, as noted by many scholars, PA levels can change within a few months, only by the influence of seasons (Matthews & Gump, 2002; Shephard, 2003). While some scholars advocate longer observation periods to examine true levels of regular/habitual PA (Shephard, 2003), studies assessing weekly (or daily) PA levels entail a certain risk of misinterpreting (multiple) current levels of PA as habitual (long-term) PA (Bergman, 2018). Furthermore, as highlighted by Klaperski (2018), it is possible that previous research has measured PA behavior in specific states of change (Klaperski, 2018). However, different states of change may indicate different demands to the organism, influencing homeostasis and allostasis (Tsatsoulis & Fountoulakis, 2006).

Furthermore, while health benefits of regular PA (including exercise) are not deniable (Reiner-Henrich, Niermann, Krapf, & Woll, 2013), greatest benefits are suggested when changing from low PA levels (inactivity) to high PA levels (Myers et al., 2015). The present sample appeared to be highly active. Therefore, results may have been confounded by a ceiling effect. Furthermore, since police officers' daily work requires various tasks including different types of PA (i.e. sitting, walking, carrying load) (Irving, Orr, & Pope, 2019; Joseph, Wiley, Orr, Schram, & Dawes, 2018), their weekly PA levels have been influenced by leisure and work time. However, PA has been shown to influence health differently depending on these areas (Holtermann et al., 2010; Li, Loerbroks, & Angerer, 2013; Li & Siegrist, 2012). Whereas PA during leisure time showed associations to increased health, occupational PA has shown lower or even reversed effects (Li et al., 2013; Schmidt, Tittlbach, Bös, & Woll, 2017). This phenomenon has been termed the PA paradox by Holtermann et al. (2010; 2018).

Taken together, the association between PA and health is multifaceted. A more distinct evaluation of PA and exercise levels, with regard to temporal variability (acute vs. regular) and areas (occupation vs leisure), wherein the behavior is performed, might improve the quality of assumptions and future recommendations.

4.2. Cardiorespiratory fitness

4.2.1 Stress-buffering effects of cardiorespiratory fitness

The hypothesized stress-buffering effects of CRF were, at least partially, supported based on the present results. CRF significantly influenced the association between chronic work stress and cardiovascular risk factors in the cross-sectional analyses. Herewith, higher levels of ERI were related to higher cardiovascular risk values, whereas higher fitness levels reduced this association. However, this result did not appear for work stress based on the JDC model, and no stress-buffering effects occurred for mental health. In the prospective analyses, the interaction between CRF and chronic work stress did not significantly predict MetS. These results are discussed for cardiovascular risk and MetS, followed by mental health.

The fact that CRF occurred as a stress-buffer in the cross-sectional analysis is in line with previous cross-sectional, as well as longitudinal studies in university students and working adults (Brown, 1991; Gerber et al., 2013c). Furthermore, a prospective study by Ortega et al. (2010) found significant main and interaction effects for CRF on the relationship between negative emotions and overall mortality risk after 15 years. A stress-buffering effect of CRF on cardiometabolic health presented in a study with 5,249 male employees by Holtermann et al. (2010). Participants with high fitness levels had significantly lower stress-related (demands component of the JDC model) risks for ischemic heart disease and all-cause mortality when work stress was high. It is noteworthy that the mean follow-up time in this study was 30 years. Especially in regard of the stress-buffering effect of CRF on MetS.

The missing stress-buffering effect of CRF in the present prospective analysis on MetS was counterintuitive. In a sample of Swedish health care workers, stress scores (single-item) were related to higher risk parameters in the low fitness group, compared to high fitness counterparts. CRF appeared as a stress-buffer to components of MetS, blood pressure and blood lipids in a cross-sectional study by Gerber et al. (2016). A 5-year prospective study with police officers found significant associations between work stress (ERI and JDC models) and the occurrence of MetS (Garbarino & Magnavita, 2015). However, cross-sectional analyses only showed significant positive associations between work stress and blood lipid levels, whereas associations with BMI, abdominal circumference, blood pressure and blood glucose remained insignificant. In a cross-sectional study with police officers, Young (1994) found no stress-buffering effects of CRF on the association of work stress and blood pressure as well as high density lipoprotein cholesterol. However, an effect occurred on smoking, indicating stress-buffering effects of CRF via health behaviors. The current analyses did not support this assumption in regard to smoking and alcohol consumption (data not shown).

A promising aspect of the present results is that they indicate cardiometabolic health benefits (including MetS) related to increased levels of CRF in a highly fit sample. These results are in line with previous research on the effects of general improvements in CRF (Lin et al., 2015). On behalf of the American Heart Association, Ross et al. (2016) outlined the profound evidence for such associations in favor of blood pressure, visceral adiposity, insulin sensitivity, as well as lipid and lipoprotein profiles, which are the components of MetS (Saklayen, 2018). Similar findings have been described for the profession of law enforcement and even among young adults (Fernström, Fernberg, Eliason, & Hurtig-Wennlöf, 2017; Huang, Webb, Zourdos, & Acevedo, 2013; Myers et al., 2019). The present findings provide important evidence regarding the global burden of CVD and the close link to work stress (Kivimaki & Kawachi, 2015; Russ et al., 2012; WHO, 2018) and strengthen the importance of CRF for cardiometabolic health.

With regard to stress-buffering effects of CRF on mental health, the present results are, to some extent, inconsistent with previous research (Gerber & Pühse, 2009; Klaperski, 2018). Klaperski (2018) showed in a recent review on laboratory studies, that physical fitness buffered the negative effects of stress on mental health in the majority of the eligible studies. However, assumed stress-buffering effects of CRF on mental health have not been supported by Ortega et al. (2010) in their prospective study (15 years mean follow-up time) with 4,888 participants. Additionally, Carmack, Boudreaux, Amaral-Melendez, Brantley, and de Moor (1999) did not find CRF to be a stress-buffer for psychological symptoms in 135 college students. As a result of their review, Gerber and Pühse (2009) resumed that stress-buffering effects were more present in physical compared to psychological health outcomes.

One explanation of the present results might be related to a missing significant association between CRF and mental health in the present sample. Based on previous research showing significant negative associations between CRF and mental health (Gerber et al., 2013c; Vancampfort et al., 2017), this result was somewhat unexpected. The overall health status in the present sample might have contributed to this result. In the present sample, prevalence rates of clinically relevant burnout symptoms (4%) and sleep complaints (7%) were considerably below the rates found in other studies (Garbarino et al., 2019; Gerber, Jonsdottir, Lindwall, & Ahlborg Jr, 2014). Furthermore, CRF levels appeared to be high in the present sample, which might confound the results by a possible ceiling effect (Collingwood, 1998). Only about 26% showed poor or very poor levels of fitness according to standards by the American College of Sports Medicine (Ferguson, 2014). The vast majority showed fair to excellent (44.5%) as well as superior (30%) fitness levels. Furthermore, the present sample was significantly younger compared to the entire police corps Basel-Stadt. However, some promising results have been shown for older populations (Clays et al., 2011; Vrijkotte, van Doornen, & de Geus, 2000). Furthermore, police officers have to take examinations of their physical and mental health in their early career, which is represented by the high fitness levels mentioned above, and possibly biased the mental health outcomes. Taken together, the relatively fit and young sample may have entailed a possible ceiling effect. Based on previous research, stress-buffering effects of CRF are unneglectable (Gerber & Pühse, 2009); therefore, future research in police officers is encouraged to examine older police officers specifically.

4.2.2 Cardiorespiratory fitness and cross-stress adaptations

In accordance with the CSA hypothesis, it was suggested that individuals with higher levels of CRF would show decreased physiological stress reactivity and increased physiological stress recovery. Results yielded limited support of the CSA hypothesis. In multilevel modeling, CRF significantly influenced the sympathetic reactivity to acute feelings of stress. This influence appeared as a blunted parasympathetic withdrawal related to individual stress experiences for higher (group) levels of CRF. However, no effects appeared for feelings of anger, positive or negative affect. While CRF was related to increased physiological recovery at night, it did not significantly influence the association between work stress and night recovery.

Comparing these results is difficult due to the limited amount of evidence for the CSA hypothesis in real-life circumstances (Gerber & Fuchs, 2018). Conflicting results were presented by Ritvanen, Louhevaara, Helin, Halonen, and Hanninen (2007). In a study with 26 teachers, perceived stress at work was assessed together with HR and blood pressure. CRF, assessed via a submaximal cycle-ergometer test, was correlated with decreased stress experiences as well as lowered HR, whereas no correlations appeared with blood pressure. However, the above mentioned study by von Haaren et al. (2016) uniquely tested the CSA hypothesis within a 20-week exercise intervention. University students in the treatment group increased their CRF levels and showed higher parasympathetic activity levels (day and night HRV) during their examination period (von Haaren et al., 2016). Results from laboratory research showed some inconsistencies regarding parasympathetic (ANS) activity as response to stressors (Forcier et al., 2006; Jackson & Dishman, 2006) (section 1.2, page 4). However, these meta-analyses did not regard newer laboratory studies which were conducted during the last 15 years. Therefore, Mücke et al. (2018) systematically reviewed evidence regarding the CSA hypothesis solely based on the TSST. Mücke et al. (2018) too found inconsistent evidence, with four out of nine studies supporting the CSA hypothesis in regard to ANS reactivity.

The fact that the current results only reached significance for feelings of stress, with small effect sizes, raises further questions about the underlying constructs. The complex association between affective-emotional constructs and psychophysiological stress responses (Schlicht, Reicherz, & Kanning, 2013) in regard to the applied psychological determinants of stress is discussed above (Publication 5). Differences in the cognitive representation of moods and emotions might be responsible for a closer association between emotions and acute stress (Kasten & Fuchs, 2018). Individual differences in brain regulatory processes in the stress response might further support different results in regard to emotions of stress against anger (Moons, Eisenberger, & Taylor, 2010). In their review and meta-analysis including healthy samples, Chida and Hamer (2008) found decreased cardiovascular reactivity related to anxiety, neuroticism or negative affect. In this respect, the current findings are consistent with results by Brondolo, Karlin, Alexander, Bobrow, and Schwartz (1999) to the extent that mood did not mediate the association between stress experiences and ANS activity. The authors presented results from a real-life study with New York traffic agents. Traffic agents' blood pressure was higher when communicating with the public compared to communication with colleagues. While mood was more negative when communicating with the public, mood did not mediate the effects on blood pressure (Brondolo et al., 1999).

In their review, Mücke et al. (2018) suggested that inconsistent results regarding SAM axis stress reactivity may be due to a "range of optimal reactivity". While increased HRV reactivity (stronger decrease in HRV) has been related to disease outcomes, higher levels of HRV in relation to psychosocial stress are generally assumed to be more favorable (Matthews, Nelesen, & Dimsdale, 2005; Pieper et al., 2007). However, the reaction to stressors may represent vital homeostatic functions. This functionality, however, may be expressed in an adequate variation of HRV. A recent review by Turner et al. (2020) supports this assumption. The authors showed that a blunted and exaggerated stress reactivity (to laboratory stressors) was related to CVD risk factors at follow-up (mean follow up time 6.4 ± 4.9 SD). Consequently, a lowered reactivity to stress might reflect poor homeostasis as well as an exaggerated reactivity (Lovallo, 2011). This assumption would further indicate that true effects might have been diminished by studies analyzing low against high HRV levels (Lovallo, 2011). This is an important issue for future research.

Taken together, the present results provided limited support for the CSA hypothesis on ANS stress reactivity and no support on ANS stress recovery. While the results suggest a more differentiated view on different emotions and mood in the psychophysiological stress process, future research is encouraged to consider measures of optimal reactivity. However, CRF was related to more favorable (increased) parasympathetic activity in day and night assessments. This is important since differences in HRV have been shown to be related to CVD (Hillebrand et al., 2013) and mortality (La Rovere et al., 1998). Therefore, the present results add valuable evidence to the current literature.

4.3 Own empirical findings and model support

As outlined in the introduction, the present research endeavor assumed stress-buffering effects of PA and CRF. Psychophysiological mechanisms were presumed in line with the CSA hypothesis with a sole focus on physiological measures related to the ANS. Under due consideration of inconsistencies in the present results, support for these models can only be given to a certain extent. In this respect the present data revealed a significant incongruence with theoretically assumed stress-buffering effects of PA. The above mentioned inconsistencies in previous studies require a more distinct examination of PA. On the other hand, current findings supported stress-buffering effects of CRF on improved cardiovascular risk factors (Holtermann et al., 2010). The CSA hypothesis was (partially) supported in terms of (decreased) physiological stress-reactivity for individuals with higher levels of CRF. The CSA hypothesis was not supported for CRF in relation to stress recovery.

While these results and previous studies still hold some inconsistencies, considerations regarding the expansion or modification of the applied model may be beneficial. The descriptions by Berntson and Cacioppo (2007) suggest at least four health influencing components: exposure, reactivity, recovery, and restoration. While exposure is the quantitative measure of perceived stressors, reactivity and recovery are understood as the strength of a (physiological) deviation from, and the time needed to return to, an individuals' baseline level. Restoration is a more unique and under-researched construct that considers "anabolic processes that refresh or repair the organism, because stress may directly impede our ability to perform these functions (i.e., disturbed sleep and impaired wound healing)" (p. 609). The inclusion of parameters reflecting restorative processes in the research of CSA may more appropriately account for the above mentioned theoretical assumptions of allostatic load (Williams, Smith, H.E., & Uchino, 2011). Furthermore, in everyday life studies, the relationship between emotions, stress and health have shown to be complex and dynamic (Zautra, Affleck, Tennen, Reich, & Davis, 2005). In the "DynAffect" model, presented by Kuppens, Oravecz, and Tuerlinckx (2010), individual' stress responses (reactivity and recovery) are dynamic fluctuations around an "emotional home base". In other words, reactivity is the sensitivity to withdraw from that home base, whereas recovery is the attracting strength that ties back to the home base (Kuppens et al., 2010). This assumption indicates that both are highly interrelated and must be handled accordingly. In line with this, Smyth et al. (2018) recently presented a stress assay capturing reactivity, recovery, and pile-up. Pile-up accounts for multiple responses in a given time period, which further quantifies the amount of challenges on homeostasis. In order to determine the validity of these different models explaining mechanisms behind potential CSA, considerably more work will need to be done.

In summary, partial support of stress-buffering effects and CSA hypothesis has been provided. Approaches that observe the theoretical model more precisely may include further stress restorative processes, and interdependent analysis of psychophysiological phenomena. In this respect, the individuality and dynamic variability of psychophysiological stress responses needs to be accounted for (Shiffman et al., 2008). Combinations of EMA and AA methods offer an excellent approach to capture fine grained observations in most realistic stress experiences which are still lacking today (Gerber & Fuchs, 2018; Kamarck et al., 2005).

4.4. Strengths

This work offers insights of high value, which is based on several strengths. By using the EMA and AA methodologies, the present research endeavor captured real-life data repeatedly and provided high external validity compared to previous studies. The combination of objective and subjective evidence enriches a research area that is predominantly based on retrospective self-reports (Kamarck et al., 2005). The profound assessment of psychological variables, including two of the most widely applied work stress models, was complemented by well accepted measures of cardiometabolic health. Herewith, important results are provided for an occupation reportedly at risk for high levels of psychosocial stress and CVD (Gerber et al., 2010b; Hartley et al., 2011; Shane, 2010). The present study uniquely applied technological advancements in capturing psychophysiological real-life data in real-time. Sophisticated statistical models appropriately accounted for intra-individual differences in stress responses. Last but not least, the concurrent assessment of PA and CRF offers important and highly demanded insights in these interrelated, yet different constructs.

4.5 Limitations

The present results must be interpreted with caution, due to some limitations. First, non-probability sampling entails a potential selection bias. Second, inconsistent associations between the assessed chronic and acute work stress measures and psychophysiological health parameters lowered the likelihood for detecting stress-buffering effects. The missing relationship regarding chronic work stress and cardiometabolic health was unexpected; however, previous research showing strong associations has often been based on longer follow-up times (Garbarino & Magnavita, 2015; Siegrist, 2005; Siegrist & Dragano, 2008). The low correlations between work stress based on the JDC model and health related outcomes has been discussed above (Publication 5), implying the need for a more critical perspective on measures of work stress (Carayon & Zijlstra, 1999; Young, 1994). While psychophysiological stress responses in real-life stress have been presented before (Kamarck et al., 2004; Zanstra & Johnston, 2011) showed, that perceived demands were not clearly limited to the workplace. While studies with specific real life stressors (i.e. exam in students) showed high correlations with psychophysiological stress responses (Davig, Larkin, & Goodie, 2000; von Haaren et al., 2016), daily stress experiences may appear differently (Zanstra & Johnston, 2011). In order to depict a broader range of varying stress levels, in addition to a longer follow-up period multiple measurements in leisure time and at work may be advantageous (Hynynen et al., 2011). Third, the present sample appeared to be highly active and showed high fitness levels. Therefore, present results may contain ceiling effects. Fourth, the concurrent analysis of psychological variables may have spuriously inflated the results. However, for a sophisticated statistical analysis, regression models and multilevel models were applied to prevent underestimations of standard errors. Fifth, some confounding factors have not been examined. These have been described for HPA axis activity, including brain regulatory mechanisms, inflammatory responses, and epigenetic factors (i.e. influencing glucocorticoids) (Gerber, 2020; Huang et al., 2013; Lee & Sawa, 2014; Puterman et al., 2010). Additionally, psychological variables, such as self-control, mental toughness, and social support, might be of interest for future research projects (Bowen et al., 2014; Gerber et al., 2013a; Sonnentag & Jelden, 2009; Uchino et al., 2007). Sixth, some studies have described the association between PA (including exercise) and stress as bidirectional (Pärkkä et al., 2009; Sonnentag & Jelden, 2009; Stults-Kolehmainen & Sinha, 2013). However, in the present analyses, stress-buffering effects of PA and CRF on health were tested assuming that PA and CRF determine/influence the interplay between psychosocial stress and health. To investigate potential reciprocal effects in the current investigation, exploratory cross-lagged correlations were performed between chronic work stress measures and stress-buffering variables at baseline and follow-up (data not shown). Correlations between the baseline values of stress-buffering variables and chronic work stress at follow-up appeared to be stronger than the reciprocal correlation, which supported the assumed stress-buffering associations. In order to better understand the nature of the triangular relationship longitudinal observations with multiple measurements are recommended (including prospective and experimental studies) (Gerber & Fuchs, 2018; Klaperski, 2018).

5. Conclusion and future directions

Psychosocial stress is a major health risk factor in modern society. While the workplace constitutes a main source of stress, physiological and mental health impairments are manifold, well-documented, and associated costs are considerable. Promising findings have been presented, suggesting stress-buffering effects of PA and CRF. However, evidence is conflicting to some extent and research is warranted to elaborate previous findings with a comprehensive methodology in externally valid conditions (Gerber & Fuchs, 2018). This project was designed to elaborate the stress-buffering effects of PA and CRF on cardiometabolic and mental health in real life. One main goal of the current study was to detect possible mechanisms in evaluating CSA on psychophysiological (ANS) stress responses. The main finding was that CRF partially occurred as a stress-buffer on cardiovascular risk factors, whereas no effects occurred for mental health. Furthermore, no stress-buffering effects of PA appeared in the data. The second major finding was that CRF partially buffered physiological stress reactivity, whereas no effect occurred on physiological stress recovery. PA did not appear to influence physiological stress reactivity or recovery.

Theoretical assumptions on stress-buffering effects and the CSA hypothesis were partially supported. To some extent, CRF was linked to improved mechanisms in outcomes that are closely linked to CVD (HRV). However, future studies may benefit from more complex research models. Furthermore, it remains questionable, whether (cumulative) acute or regular PA (including exercise) functions as a stress-buffer (Klaperski, 2018; Ritvanen et al., 2007). Some authors further suggest that effects are based on an interaction between these two and resulting fitness, which needs further examination (Hamer, 2012).

Longer follow-up periods including multiple measurements are needed for the examination of long-term effects and mechanisms of dynamically changing psychophysiological stress responses in everyday life. Therefore, a strength of the present research was the design, which accounted for intra-individual variability, and used multiple measurements of personally relevant real-life stressors. However, future research would benefit from a more distinctive elaboration of PA, regarding differences between exercise and PA, current and habitual PA levels, as well as leisure time and occupational PA. Another strength of the present study is the concurrent assessment of PA and CRF. Future research elaborating the differences and interactions between PA and fitness is warranted. Resulting insights might help to find appropriate recommendations and preventive measures to influence health, and perhaps, the interaction between stress and health.

The present findings must be cautiously interpreted because of the above mentioned limitations. Notwithstanding these limitations, the study has shown that, in an active and highly fit sample of police officers, CRF was a reliable predictor for lowered cardiovascular risk factors, including MetS. CVDs are a global burden. The clinical importance to increase and maintain cardiometabolic health indicates the promotion of CRF for preventive reasons. The benefits would serve individual's well-being, but also public health purposes especially in mentally and physically demanding occupations. In the occupation of policing, health improvements resemble a societal and governmental interest. Therefore, the consistent and routine measurement of CRF should be equally addressed in occupational health programs for police officers, as constant efforts to encourage individuals to improve and preserve CRF levels. In order to support this health behavior and credibly endorse company culture which values CRF, employers are encouraged to create training and education facilities, and incorporate them into working schedules. Health professionals might apply HRV measuring methods to examine and track an individual's health status and guide workplace interventions in police officers, which has shown to be applicable in the present study. Albeit high levels of occupational stress were associated with more burnout symptoms, sleep complaints and increased overall psychological stress, PA and CRF did not significantly buffer these relationships. Based on these results, state and local health departments, as well as occupational health managers are encouraged to support mental health in police officers through additional efforts.

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Appendix

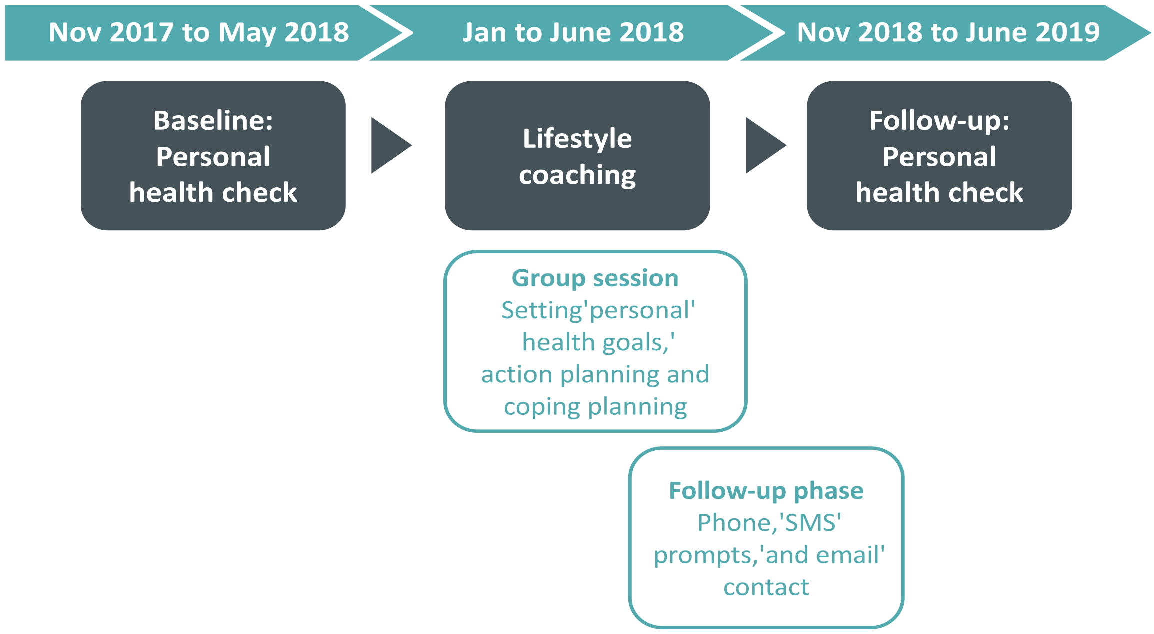
Appendix 1: Shift work cycle of the police Basel-Stadt

1. Tag: ganztägiger Dienst	7.30-12.30	Uhr	14.00-19.00	Uhr
2. Tag: Nachmittagsdienst			12.30-19.00	Uhr
3. Tag: Vormittags-/Spätdienst	7.30-12.30	Uhr	19.00-24.00	Uhr
4. Tag: Nachtdienst/Ruhetag	0.00- 7.30	Uhr		
5. Tag: freier Tag				
6. Tag: freier Tag				
1. Tag: ganztägiger Dienst	7.30-12.30	Uhr	14.00-19.00	Uhr
usw.				

Retrieved from https://www.polizei.bs.ch/karriere/polizist--in/arbeitszeiten-ferien.html on May, 18th, 2020.

Appendix 2: Study procedure

Study flowchart:



Procedure during baseline and follow-up measurement:

Appendix 3: Informed consent

Type of Research Project:	Longitudinal study
Risk Categorisation:	A
Project Leader:	Prof. Dr. Markus Gerber Head Division Sport and Psychosocial Health Department of Sport, Exercise and Health University of Basel, Birsstr. 320 B CH-4052 Basel
Doctoral Students:	René Schilling Department of Sport, Exercise and Health University of Basel
Cooperation Partners	Simon Spoerri Justiz- und Sicherheitsdepartement des Kantons Basel-Stadt Kantonspolizei, Leiter Sicherheitspolizei Spiegelgasse 6, 4001 Basel Daniela Montinari Justiz- und Sicherheitsdepartement des Kantons Basel-Stadt Kantonspolizei, Leiterin Ausbildung & Rekrutierung General Guisan-Strasse 29 4054 Basel
Location of Study:	Basel, Switzerland
Project Duration:	01.10.2017 bis 01.06.2019
Project Plan Version and Date:	Version 1, 15.08.2017

The project leader has approved the research plan version 1 (dated 15 August 2017), and confirms hereby to conduct the project according to the plan, the current version of the World Medical Association Declaration of Helsinki (Principles of Good Clinical Practice (GCP) and the local legally applicable requirements. The PhD student confirms that he has read and agreed on the study protocol.

Einwilligungserklärung

Schriftliche Einwilligungserklärung zur Teilnahme an einem Studienprojekt

Bitte lesen Sie dieses Formular sorgfältig durch. Bitte fragen Sie, wenn Sie etwas nicht verstehen oder wissen möchten. Für die Teilnahme ist Ihre schriftliche Einwilligung notwendig.

BASEC-Nummer (nach Einreichung):	2017-01477
Titel der Studie (wissenschaftlich und Laiensprache):	The influence of physical activity on stress reactivity in real-life stress situations
Verantwortliche Institution (Sponsor mit Adresse):	Departement für Sport, Bewegung und Gesundheit
Ort der Durchführung:	General Guisan Strasse 29, 4054 Basel
Verantwortliche Prüfpersonen am Studienort: Name und Vorname in Druckbuchstaben:	Prof. Dr. Markus Gerber René Schilling
Teilnehmerin/Teilnehmer: Name und Vorname in Druckbuchstaben: Geburtsdatum:	☐ weiblich ☐ männlich

- Ich wurde von der unterzeichnenden Prüfperson mündlich und schriftlich über den Zweck, den Ablauf der Studie mit dem über mögliche Vor- und Nachteile sowie über eventuelle Risiken informiert.
- Ich nehme an dieser Studie freiwillig teil und akzeptiere den Inhalt der abgegebenen schriftlichen Information. Ich hatte genügend Zeit, meine Entscheidung zu treffen.
- Meine Fragen im Zusammenhang mit der Teilnahme an dieser Studie sind mir beantwortet worden. Ich behalte die schriftliche Information und erhalte eine Kopie meiner schriftlichen Einwilligungserklärung.
- Ich bin einverstanden, dass die zuständigen Fachleute des Sponsors, der zuständigen Ethikkommission zu Prüf- und Kontrollzwecken in meine unverschlüsselten Daten Einsicht nehmen dürfen, jedoch unter strikter Einhaltung der Vertraulichkeit.
- Bei Studienergebnissen, die direkt meine Gesundheit betreffen, werde ich informiert. Wenn ich das nicht wünsche, informiere ich meine Prüfperson.
- Falls zutreffend: Ich weiss, dass meine gesundheitsbezogenen und persönlichen Daten (und Proben) nur in verschlüsselter Form zu Forschungszwecken für diese Studie weitergegeben werden können.
- Ich kann jederzeit und ohne Angabe von Gründen von der Studienteilnahme zurücktreten, ohne dass mir daraus Nachteile entstehen würden. Die bis zum Rücktritt erhobenen Daten werden für die Auswertung zur Studie verwendet.
- Die Haftpflichtversicherung der Institution kommt für allfällige Schäden auf.
- Ich bin mir bewusst, dass die in der Teilnehmerinformation genannten Pflichten einzuhalten sind. Im Interesse meiner Gesundheit kann mich die Prüfperson jederzeit von der Studie ausschliessen.

Ort, Datum	Unterschrift Teilnehmerin/Teilnehmer

Bestätigung der Prüfperson: Hiermit bestätige ich, dass ich dieser Teilnehmerin/ diesem Teilnehmer Wesen, Bedeutung und Tragweite der Studie erläutert habe. Ich versichere, alle im Zusammenhang mit dieser Studie stehenden Verpflichtungen gemäss des geltenden Rechts zu erfüllen. Sollte ich zu irgendeinem Zeitpunkt während der Durchführung der Studie von Aspekten erfahren, welche die Bereitschaft der Teilnehmerin/ des Teilnehmers zur Teilnahme an der Studie beeinflussen könnten, werde ich sie/ ihn umgehend darüber informieren.

Ort, Datum	Name und Vorname der Prüfperson in Druckbuchstaben Unterschrift der Prüfperson

Appendix 4: Online questionnaire

EvaSys	Fragebogen zum Stresserleben und zur Gesundheit	Electric Paper

Universität Basel

Bitte so markieren: ☐ ☒ ☐ ☐ ☐ Bitte verwenden Sie einen Kugelschreiber oder nicht zu starken Filzstift. Dieser Fragebogen wird maschinell erfasst.
Korrektur: ☐ ■ ☐ ☒ ☐ Bitte beachten Sie im Interesse einer optimalen Datenerfassung die links gegebenen Hinweise beim Ausfüllen.

Einleitung

Liebe Mitarbeiter/-innen der Kantonspolizei Basel-Stadt,

Die folgende Befragung ist Teil des individuellen Gesundheitschecks und dient dazu, Informationen über Ihren aktuellen Stressbelastungsgrad und Ihr mentales Wohlbefinden zu erhalten. Wir möchten Sie deshalb bitten, die folgenden Fragen möglichst aufrichtig und spontan zu beantworten. Das Ausfüllen des Fragebogens dauert etwa 30 Minuten. Es gibt keine richtigen oder falschen Antworten, es zählt einzig Ihre Einschätzung. Die Daten werden ausschliesslich zu Forschungszwecken verwendet. Hierzu werden alle Angaben, die Rückschlüsse auf Ihre Person ermöglichen, verschlüsselt und streng vertraulich behandelt. Ihr Arbeitgeber erhält KEINEN Einblick in Ihre persönlichen Daten.

Herzlichen Dank für Ihre Mitarbeit.
Basel, November 2017

Teil 1: Angaben zur Person

Studien - ID (4-stellige ID, in der Email-Mitteilung ersichtlich)

☐☐☐☐

Welches Geschlecht haben Sie? ☐ weiblich ☐ männlich

Wie lange arbeiten Sie bereits bei der Kantonspolizei Basel-Stadt? (z.B. 06 Jahre und 10 Monate)

☐☐ Jahre ☐☐ Monate

Wie alt sind Sie?

☐☐ Jahre

Welches ist Ihre aktuelle Beziehungssituation? ☐ alleinstehend / single / getrennt ☐ verheiratet / in fester Beziehung

Welches ist Ihre höchste Ausbildung (ohne die polizeiinterne Ausbildung)?
☐ obligatorische Schule (oder einige Schuljahre)
☐ Berufslehre ohne Berufsmaturität
☐ Berufslehre mit Berufsmaturität
☐ höhere Fachschule / Berufsprüfung / Fachprüfung
☐ gymnasiale Maturität / Fachmittelschule
☐ Studium Universität / Pädagogische Hochschule / Fachhochschule
☐ andere

Falls andere, welche?

Haben Sie Kinder, die noch zu Hause wohnen? ☐ Ja ☐ Nein

Wie viele?

☐☐ Kind(er)

Kümmern Sie sich derzeit hauptverantwortlich um eine pflegebedürftige Person? ☐ Ja ☐ Nein

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Teil 1: Angaben zur Person [Fortsetzung]

Arbeiten Sie im ...? ☐ Tourendienst ☐ Tagdienst

Welche berufliche Stellung haben Sie?
☐ Mitarbeiter/in ☐ Angehörige/r des unteren Kaders ☐ Angehörige/r des mittleren Kaders
☐ Angehörige/r des oberen Kaders

Von wie vielen Personen sind Sie der/die unmittelbare Vorgesetzte? (z.B. 000 oder 015)

☐☐☐ Personen

Wie hoch war Ihr durchschnittlicher Beschäftigungsgrad über die letzten 6 Monate? Bei Antworten dazwischen bitte die nächst tiefere Option wählen.
☐ 0% ☐ 10% ☐ 20%
☐ 30% ☐ 40% ☐ 50%
☐ 60% ☐ 70% ☐ 80%
☐ 90% ☐ 100%

Nehmen Sie regelmässig Medikamente ein? ☐ Ja ☐ Nein

Falls ja, welche? (Name und Grund)

Waren Sie bereits einmal in ärztlicher Behandlung / Sind Sie aktuell in Behandlung ...

	Nein	Ja, in Behandlung gewesen	Ja, aktuell in Behandlung
wegen hohem Blutdruck?	☐	☐	☐
wegen Rheumatismus oder Rückenschmerzen?	☐	☐	☐
wegen Heuschnupfen oder sonstigen Allergien?	☐	☐	☐
wegen Herzklopfen, Herzrasen, Herzstolpern oder Herzinfarkt?	☐	☐	☐
wegen Kopfschmerzen, Druck im Kopf oder Gesichtsschmerzen?	☐	☐	☐
wegen Einschlaf- oder Durchschlafstörungen?	☐	☐	☐
wegen einem Nervenzusammenbruch oder einer Depression?	☐	☐	☐
wegen einer anderen physischen Erkrankung?	☐	☐	☐

Falls ja, welche? (bezieht sich nur auf die letzte Teilfrage)

wegen einer anderen psychischen Erkrankung?	☐	☐	☐

Falls ja, welche? (bezieht sich nur auf die letzte Teilfrage)

Hatten Sie im letzten Jahr Kreuz- oder Rückenschmerzen?

Stärke	gar nicht ☐	☐	☐	☐ stark	
Häufigkeit	nie ☐	☐	☐	☐ ständig	

	nie	bis 3 Monate	bis 6 Monate	6 Monate und länger
Dauer	☐	☐	☐	☐

Teil 2: Gesundheitsverhalten

Kreuzen Sie die Antwortoption an, die am Besten beschreibt, wie Sie sich während **den letzten drei Monaten** in Ihrer Freizeit bewegt haben. Lesen Sie bitte zuerst alle Antwortoptionen, bevor Sie ein Kreuz machen.

- ☐ Meist stillsitzend, manchmal Spaziergänge, leichtere Gartenarbeiten und/oder Ähnliches.
- ☐ Leichtere körperliche Anstrengung mindestens einige Stunden pro Woche, zum Beispiel Spaziergänge oder Radfahren (z.B. zur Arbeit und zurück), Tanz, normale Gartenarbeiten und/oder Ähnliches.
- ☐ Mittelmässig anstrengende körperliche Aktivität mindestens einige Stunden pro Woche, zum Beispiel Tennis, Schwimmen, Jogging, Aerobic, Radfahren/ Spinning, intensives Tanzen, Fussball, Unihockey, schwere Gartenarbeit und/ oder Ähnliches.
- ☐ Hartes Training, regelmässig und mehrmals pro Woche, total mindestens 5 Stunden, grosse körperliche Anstrengung.

Denken Sie, dass Sie sich für Ihre Gesundheit genug bewegen? ☐ Ja ☐ Nein

Wie schätzen Sie Ihre Fitness ein?

	1	2	3	4	5	6	7	8	9	10	
sehr schlecht	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	ausgezeichnet

Wieviele Zigaretten (inkl. Zigarren, Zigarillos und Pfeifen, ohne E-Zigaretten) rauchen Sie im Durchschnitt pro Tag?

keine	weniger als 1	1-9	10-19	20 und mehr
☐	☐	☐	☐	☐

An wie vielen Tagen pro Woche trinken Sie durchschnittlich Alkohol?

☐ kein Tag ☐ 1 Tag ☐ 2 Tage
☐ 3 Tage ☐ 4 Tage ☐ 5 Tage
☐ 6 Tage ☐ 7 Tage

Wenn Sie Alkohol zu sich nehmen, wie viele Drinks konsumieren Sie pro Trinktag? Ein Drink entspricht 0,33 l Bier, 0,15 l Wein/Sekt oder 1 einfachen Schnaps (40 %, z.B. Weinbrand, ca. 4 cl). Anzahl Drinks (z.B. 02)

☐☐ Drinks

Teil 3: Stressbelastung

Im folgenden Abschnitt möchten wir mehr über Ihre Stressbelastung erfahren. Zunächst einige allgemeine Fragen:

	nie	fast nie	manchmal	ziemlich oft	sehr oft
Wie oft haben Sie **im letzten Monat** gefühlt, dass Sie nicht in der Lage waren, wichtige Dinge in Ihrem Leben zu kontrollieren?	☐	☐	☐	☐	☐

Teil 3: Stressbelastung [Fortsetzung]

Wie oft haben Sie **im letzten Monat** in Ihre Fähigkeiten, Ihre persönlichen Probleme zu lösen, Vertrauen gehabt?	☐	☐	☐	☐	☐
Wie oft haben Sie **im letzten Monat** gefühlt, dass Dinge so gelaufen sind, wie Sie sich das dachten?	☐	☐	☐	☐	☐
Wie oft haben Sie **im letzten Monat** gefühlt, dass sich Schwierigkeiten so stark anhäufen, dass Sie sie nicht bewältigen können?	☐	☐	☐	☐	☐

In der Folge geht es darum, inwieweit Sie von bestimmten Stressquellen bei der Arbeit belastet werden.

	Stimme gar nicht zu	Stimme eher nicht zu	Stimme eher zu	Stimme voll zu
Aufgrund des hohen Arbeitsaufkommens besteht häufig grosser Zeitdruck.	☐	☐	☐	☐
Bei meiner Arbeit werde ich häufig unterbrochen und gestört.	☐	☐	☐	☐
Bei meiner Arbeit habe ich viel Verantwortung zu tragen.	☐	☐	☐	☐
Ich bin häufig gezwungen, Überstunden zu machen.	☐	☐	☐	☐
Meine Arbeit ist körperlich anstrengend.	☐	☐	☐	☐
Im Laufe der letzten Jahre ist meine Arbeit immer mehr geworden.	☐	☐	☐	☐
Ich erhalte von meinen Vorgesetzten und Kollegen/-innen die Anerkennung, die ich verdiene.	☐	☐	☐	☐
Ich erhalte in schwierigen Situationen angemessene Unterstützung.	☐	☐	☐	☐
Ich werde bei meiner Arbeit ungerecht behandelt.	☐	☐	☐	☐
Die Aufstiegschancen in meinem Bereich sind schlecht.	☐	☐	☐	☐
Wenn ich an all die erbrachten Leistungen denke, halte ich mein Gehalt /meinen Lohn für angemessen.	☐	☐	☐	☐
Ich erfahre - oder erwarte - eine Verschlechterung meiner Arbeitssituation.	☐	☐	☐	☐
Mein eigener Arbeitsplatz ist gefährdet.	☐	☐	☐	☐
Wenn ich an meine Ausbildung denke, halte ich meine berufliche Stellung fu r angemessen.	☐	☐	☐	☐
Wenn ich an all die erbrachten Leistungen und Anstrengungen denke, halte ich die erfahrene Anerkennung für angemessen.	☐	☐	☐	☐
Wenn ich an all die erbrachten Leistungen und Anstrengungen denke, halte ich meine beruflichen Perspektiven für angemessen.	☐	☐	☐	☐

	Ja, häufig	Ja, manchmal	Nein, selten	Nein, so gut wie nie
Meine Arbeit erfordert sehr schnelles Arbeiten.	☐	☐	☐	☐
Meine Arbeit erfordert sehr hartes Arbeiten.	☐	☐	☐	☐
Ich habe genug Zeit, meine Arbeit zu erledigen.	☐	☐	☐	☐
An mich werden durch andere widersprüchliche Anforderungen gestellt.	☐	☐	☐	☐
Meine Arbeit erfordert es, dass ich Neues lerne.	☐	☐	☐	☐
Meine Arbeit erfordert ein hohes Niveau an Fähigkeiten.	☐	☐	☐	☐

X

Teil 3: Stressbelastung [Fortsetzung]

Meine Arbeit erfordert es, kreativ zu sein.	☐	☐	☐	☐
Meine Arbeit beinhaltet eine Menge von sich wiederholenden Tätigkeiten.	☐	☐	☐	☐
Ich kann selber entscheiden, wie ich meine Arbeit erledige.	☐	☐	☐	☐
In Rahmen meiner Arbeit kann ich selber entscheiden, welche Aufgaben es zu erledigen gilt.	☐	☐	☐	☐

Als nächstes folgen einige Fragen zur Vereinbarkeit von Familie und Arbeit.

	Stimme überhaupt nicht zu	- -	-	Weder noch	+	+ +	Stimme genau zu
Meine Arbeit hindert mich daran, genügend schöne Momente mit meiner Familie zu verbringen.	☐	☐	☐	☐	☐	☐	☐
Am Ende des Tages habe ich keine Zeit, um alles zu erledigen, wenn ich zu Hause bin (z.B. Haushalt, Hobbies).	☐	☐	☐	☐	☐	☐	☐
Aufgrund meiner beruflichen Pflichten kommt meine Familie zu kurz.	☐	☐	☐	☐	☐	☐	☐
Meine Arbeit hat einen negativen Effekt auf mein Familienleben.	☐	☐	☐	☐	☐	☐	☐
Aufgrund meiner Arbeit bin ich zu Hause oft empfindlich und leicht reizbar.	☐	☐	☐	☐	☐	☐	☐
Meine Arbeitsleistung leidet unter meinen persönlichen Familienverpflichtungen.	☐	☐	☐	☐	☐	☐	☐
Meine familiären Pflichten/Sorgen lenken mich bei der Arbeit oft ab.	☐	☐	☐	☐	☐	☐	☐
Wenn ich keine Familie hätte, wäre ich ein/e bessere/r Angestellte/r.	☐	☐	☐	☐	☐	☐	☐
Meine Familie hat einen negativen Einfluss auf meine tagtäglichen Aufgaben.	☐	☐	☐	☐	☐	☐	☐
Während der Arbeit fällt es mir schwer, mich zu konzentrieren, weil ich von familiären Pflichten so erschöpft bin.	☐	☐	☐	☐	☐	☐	☐

Teil 4: Schlaf

Im nächsten Teil geht es um das Thema Schlaf:

Schätzen Sie ein, inwiefern Ihr Schlaf **in den letzten beiden Wochen** beeinträchtigt wurde durch ...

	gar nicht	leicht	mittel	schwer	sehr schwer
a) Einschlafstörungen	☐	☐	☐	☐	☐
b) Durchschlafstörungen	☐	☐	☐	☐	☐
c) Früherwachen	☐	☐	☐	☐	☐

	sehr zufrieden	zufrieden	neutral	unzufrieden	sehr unzufrieden
Wie zufrieden/unzufrieden sind Sie mit Ihrem gegenwärtigen Schlaf?	☐	☐	☐	☐	☐

Teil 4: Schlaf [Fortsetzung]

	überhaupt nicht	ein wenig	mässig	stark	sehr stark
Wie stark ist Ihre Leistungsfähigkeit während der Arbeit durch einen schlechten Schlaf beeinträchtigt?	☐	☐	☐	☐	☐
Wie stark glauben Sie, dass andere Personen die Auswirkung ihres (schlechten) Schlafes auf Ihre Lebensqualität wahrnehmen?	☐	☐	☐	☐	☐
Inwiefern macht Ihnen Ihr (schlechter) Schlaf zur Zeit Sorgen?	☐	☐	☐	☐	☐

Teil 5: Mentales Wohlbefinden

Im folgenden Abschnitt geht es um Ihr mentales Wohlbefinden.

Wie oft haben Sie sich in den **letzten drei Monaten** bei der Arbeit so gefühlt?

	nie/ fast nie	sehr selten	ziemlich selten	manchmal	ziemlich oft	sehr oft	immer/ fast immer
Ich fühlte mich müde.	☐	☐	☐	☐	☐	☐	☐
Ich hatte keine Energie, um morgens zur Arbeit zu gehen.	☐	☐	☐	☐	☐	☐	☐
Ich fühlte mich körperlich ausgelaugt.	☐	☐	☐	☐	☐	☐	☐
Ich hatte die Nase voll.	☐	☐	☐	☐	☐	☐	☐
Ich hatte das Gefühl, dass meine Batterien leer sind.	☐	☐	☐	☐	☐	☐	☐
Ich fühlte mich ausgebrannt.	☐	☐	☐	☐	☐	☐	☐
Mein Denken war verlangsamt.	☐	☐	☐	☐	☐	☐	☐
Ich hatte Schwierigkeiten, mich zu konzentrieren.	☐	☐	☐	☐	☐	☐	☐
Ich hatte das Gefühl, nicht klar zu denken.	☐	☐	☐	☐	☐	☐	☐
Ich hatte das Gefühl, beim Denken nicht bei der Sache zu sein.	☐	☐	☐	☐	☐	☐	☐
Ich hatte Schwierigkeiten, über komplexe Dinge nachzudenken.	☐	☐	☐	☐	☐	☐	☐
Ich fühlte mich nicht in der Lage, mich auf die Bedürfnisse von Arbeitskollegen und Kunden einzustellen.	☐	☐	☐	☐	☐	☐	☐
Ich fühlte mich nicht in der Lage, gefühlsmässig in Arbeitskollegen/-innen oder Bürger/-innen zu investieren.	☐	☐	☐	☐	☐	☐	☐
Ich fühlte mich nicht in der Lage, mich in Arbeitskollegen/-innen oder Bürger/-innen hineinzuversetzen.	☐	☐	☐	☐	☐	☐	☐

Hier einige weitere Fragen zu Ihrem Wohlbefinden **in den letzten Wochen**:

	Nein, gar nicht	So wie üblich	Schlechter als üblich	Viel schlechter als übl.
Haben Sie in den letzten Wochen wegen Sorgen weniger geschlafen?	☐	☐	☐	☐

Teil 5: Mentales Wohlbefinden [Fortsetzung]

	Nein, gar nicht	Nicht mehr als üblich	Mehr als üblich	Viel mehr als üblich
Haben Sie in den letzten Wochen das Gefühl gehabt, dauernd unter Druck zu stehen?	☐	☐	☐	☐

	Besser als üblich	So wie üblich	Schlechter als üblich	Viel schlechter als übl.
Haben Sie sich in den letzten Wochen auf das, was Sie gemacht haben, konzentrieren können?	☐	☐	☐	☐

	Mehr als üblich	So wie üblich	Weniger als üblich	Viel weniger als üblich
Haben Sie in den letzten Wochen das Gefühl gehabt, für etwas nützlich zu sein?	☐	☐	☐	☐

	Besser als üblich	So wie üblich	Weniger als üblich	Viel weniger als üblich
Haben Sie in den letzten Wochen das Gefühl gehabt, mit Ihren Problemen umgehen zu können?	☐	☐	☐	☐

	Nein, gar nicht	So wie üblich	Schwerer als üblich	Viel schwerer als üblich
Ist es Ihnen in den letzten Wochen schwer gefallen, Entscheidungen zu treffen?	☐	☐	☐	☐

Nein, gar nicht | Nicht schlechter als übl. | Schlechter als üblich | Viel schlechter als übl.

Teil 5: Mentales Wohlbefinden [Fortsetzung]

Haben Sie in den letzten Wochen den Eindruck gehabt, dass Sie mit Ihren Schwierigkeiten nicht zurecht gekommen sind?	☐	☐	☐	☐

	Mehr als üblich	So wie üblich	Weniger als üblich	Viel weniger als üblich
Alles in allem, haben Sie sich in den letzten Wochen einigermassen zufrieden gefühlt?	☐	☐	☐	☐

	Mehr als üblich	So wie üblich	Weniger als üblich	Viel weniger als üblich
Konnten Sie in den letzten Wochen Ihren Alltagsverpflichtungen mit Freude nachgehen?	☐	☐	☐	☐

	Nein, gar nicht	Nicht mehr als üblich	Mehr als üblich	Viel mehr als üblich
Haben Sie sich in den letzten Wochen unglücklich und deprimiert gefühlt?	☐	☐	☐	☐

	Nein, gar nicht	Nicht mehr als üblich	Mehr als üblich	Viel mehr als üblich
Haben Sie in den letzten Wochen einen Mangel an Selbstvertrauen gespürt?	☐	☐	☐	☐

	Nein, gar nicht	Nicht mehr als üblich	Mehr als üblich	Viel mehr als üblich
Haben Sie sich in den letzten Wochen wertlos gefühlt?	☐	☐	☐	☐

Teil 6: Persönliche Einstellungen und Verhaltenstendenzen

Bald haben Sie es geschafft. Nun stellen wir Ihnen einige Fragen zu Ihren persönlichen Einstellungen und bevorzugten Verhaltenstendenzen. Geben Sie möglichst spontan Antwort.

Teil 6: Persönliche Einstellungen und Verhaltenstendenzen [Fortsetzung]

	stimmt überhaupt nicht	stimmt nicht	weder noch	stimmt	stimmt genau
Selbst wenn ich unter starkem Druck stehe, bleibe ich normalerweise ruhig und gelassen.	☐	☐	☐	☐	☐
Ich neige dazu, mir über Dinge Sorgen zu machen, bevor sie überhaupt passiert sind.	☐	☐	☐	☐	☐
Es fällt mir normalerweise schwer, mich für Aufgaben zu begeistern, die ich zu tun habe.	☐	☐	☐	☐	☐
Ich kann mit allen auftauchenden Problemen grundsätzlich gut umgehen.	☐	☐	☐	☐	☐
Ich habe grundsätzlich das Gefühl, ein wertvoller Mensch zu sein.	☐	☐	☐	☐	☐
„Ich weiss gar nicht, wo ich anfangen soll"; dieses Gefühl habe ich normalerweise, wenn ich mehrere Dinge gleichzeitig erledigen soll.	☐	☐	☐	☐	☐
Wenn ich etwas mitzuteilen habe, sage ich normalerweise meine Meinung.	☐	☐	☐	☐	☐
Wenn ich Fehler mache, rege ich mich normalerweise auch noch nach Tagen darüber auf.	☐	☐	☐	☐	☐
Ich neige dazu, in Diskussionen klein bei zu geben, auch wenn ich mir einer Sache sicher bin.	☐	☐	☐	☐	☐
Ich habe grundsätzlich das Gefühl, die Kontrolle zu haben.	☐	☐	☐	☐	☐
Ich wünsche mir oft, mein Leben wäre vorhersehbarer.	☐	☐	☐	☐	☐
Wenn ich müde bin, fällt es mir schwer, in die Gänge zu kommen.	☐	☐	☐	☐	☐
Ich bin grundsätzlich in der Lage, schnell zu reagieren, wenn etwas Unerwartetes geschieht.	☐	☐	☐	☐	☐
Egal wie schlimm die Dinge auch sein mögen, ich denke normalerweise, dass sie am Ende gut ausgehen.	☐	☐	☐	☐	☐
Ich schaue grundsätzlich auf die schönen Dinge des Lebens.	☐	☐	☐	☐	☐
Mir fällt es grundsätzlich schwer, mich zu entspannen.	☐	☐	☐	☐	☐
Wenn ich müde bin, fällt es mir normalerweise schwer, mich geistig anzustrengen.	☐	☐	☐	☐	☐
Wenn ich das Gefühl habe, dass jemand Unrecht hat, fällt es mir nicht schwer, es ihm/ihr zu sagen.	☐	☐	☐	☐	☐

	völlig unzutreffend	eher nicht zutreffend	weder noch	eher zutreffend	ganz genau zutreffend
Ich bin gut darin, Versuchungen zu widerstehen.	☐	☐	☐	☐	☐
Es fällt mir schwer, schlechte Gewohnheiten abzulegen.	☐	☐	☐	☐	☐
Ich bin eher „faul" veranlagt.	☐	☐	☐	☐	☐
Ich sage manchmal unpassende Dinge.	☐	☐	☐	☐	☐
Ich tue manchmal Dinge, die schlecht für mich sind, wenn sie mir Spass machen.	☐	☐	☐	☐	☐
Ich wünschte, ich hätte mehr Selbstdisziplin.	☐	☐	☐	☐	☐
Angenehme Aktivitäten und Vergnügen hindern mich manchmal daran, meine Arbeit zu machen.	☐	☐	☐	☐	☐
Es fällt mir schwer, mich zu konzentrieren.	☐	☐	☐	☐	☐
Ich kann effektiv auf langfristige Ziele hinarbeiten.	☐	☐	☐	☐	☐

Teil 6: Persönliche Einstellungen und Verhaltenstendenzen [Fortsetzung]

Manchmal kann ich mich selbst nicht daran hindern, etwas zu tun, obwohl ich weiss, dass es falsch ist.	☐	☐	☐	☐	☐
Ich handle oft, ohne alle Alternativen durchdacht zu haben.	☐	☐	☐	☐	☐
Ich lehne Dinge ab, die schlecht für mich sind.	☐	☐	☐	☐	☐

Teil 7: Wahrnehmung des sozialen Umfelds

Zum Abschluss möchten wir von Ihnen erfahren, wie Sie Ihr soziales Umfeld wahrnehmen:

	nie	fast nie	manchmal	ziemlich oft	sehr oft
Wenn Sie ein Gespräch brauchen, gibt es jemanden, der Ihnen richtig zuhört?	☐	☐	☐	☐	☐
Gibt es jemanden, der Ihnen Liebe und Zuneigung zeigt?	☐	☐	☐	☐	☐
Gibt es jemanden, der Ihnen einen guten Rat gibt, wenn Sie ein Problem haben?	☐	☐	☐	☐	☐
Können Sie auf jemanden zählen, der Sie emotional unterstützt (z. B. mit Ihnen über Ihre Sorgen spricht oder Ihnen bei schwierigen Entscheidungen hilft)?	☐	☐	☐	☐	☐
Haben Sie zu einem Menschen, dem Sie sich nahe fühlen und dem Sie vertrauen, so viel Kontakt, wie Sie sich das wünschen?	☐	☐	☐	☐	☐

Abschliessendes

Sie sind am Ende des Fragebogens angelangt. Wir bedanken uns ganz herzlich, dass Sie sich die Zeit genommen haben, an der Befragung teilzunehmen. Nach Auswertung der Daten werden wir Ihnen Ihr persönliches Gesundheitsprofil erstellen. Wir wünschen Ihnen eine gute und vor allem stressfreie Zeit!

Das Untersuchungsteam

Für weitere Fragen und Auskünfte stehen wir Ihnen gerne zur Verfügung:

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Appendix 5: Ecological momentary assessment questions and sampling scheme

Waren Sie in den letzten 15 Minuten körperlich aktiv?
(Ja / Nein)

Haben Sie die letzten 15 Minuten körperlich in Ruhe verbracht?
(Ja / Nein)

Wie fühlen Sie sich gerade?
1. niedergeschlagen?
2. freudig erregt?
3. genervt?
4. zufrieden?
5. reizbar?
6. begeistert?
7. voller Energie?
8. nervös?
9. voller Selbstvertrauen?
10. besorgt?

(Likert Skala 1-5; 1=gar nicht; 2=ein bisschen; 3=mittelmässig; 4=erheblich; 5=extrem)

Wie gestresst fühlen Sie sich gerade?
(5 Punkt Likert Skala 1-5; 1=gar nicht; 3=mittelmässig; 5=sehr)

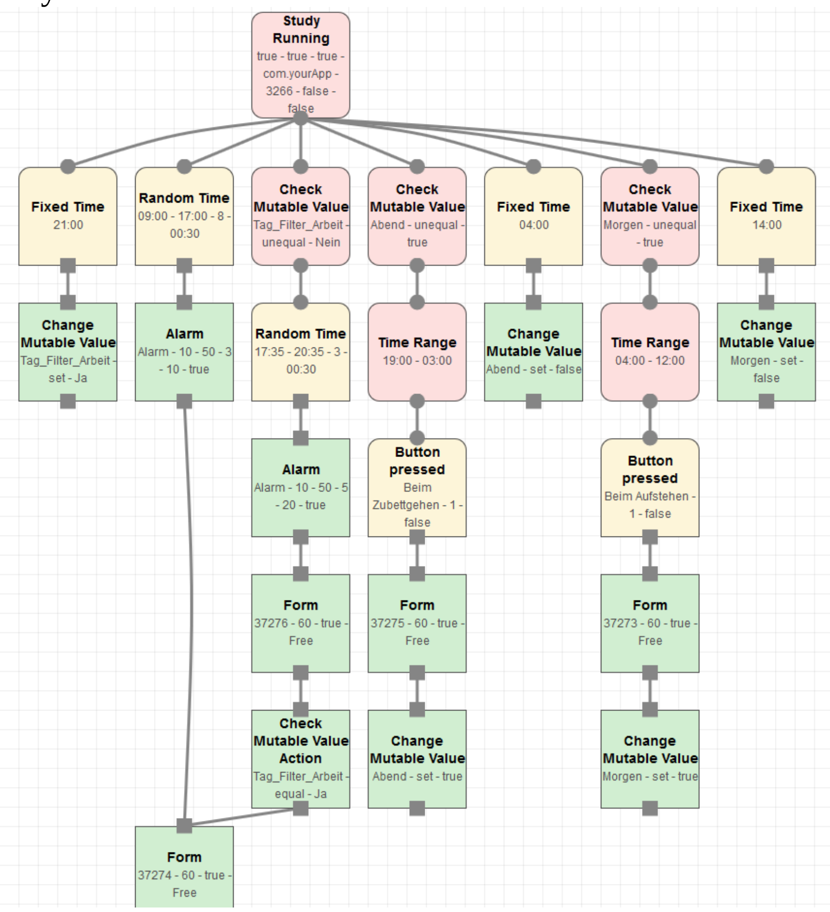
Wie sehr haben Sie sich in den letzten 10 Minuten über irgendetwas geärgert?
(5 Punkt Likert Skala 1-5; 1=gar nicht; 3=mittelmässig; 5=sehr)

Welche der folgenden Situationen habe Sie in den letzten 10 Minuten erlebt?
1. Meinungsverschiedenheiten oder Streit mit anderen
2. Arbeiten unter Zeitdruck
3. Zu hohes Arbeitsaufkommen
4. Ungerechte Behandlung durch Kollegen oder Vorgesetzte
5. Ungerechte Behandlung durch Bürger
6. Hoher Erwartungsdruck
7. Erledigung unangenehmer Aufgaben
8. Etwas nicht vollständig im Griff haben

(Ja / Nein)

Sampling scheme (Movisens *XS*)

Day shift:



Night shift: