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Examining the Connection of Domain-specific Health Literacy with Health Behaviour and Health in German Office Workers

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List of Abbreviations

AIC	Akaike's Information Criterion
BIC	Bayesian Information Criterion
BMI	Body-Mass Index
CFI	Comparative Fit Index
CI	Confidence Intervals
DB	Dietary Behaviour
FFQ	Food Frequency Questionnaire
FLI	Fatty-Liver Index
GGT	γ-Glutamyltransferase
HDL	High-density Lipoprotein
HrQoL	Health-related Quality of Life
LTPA	Leisure-time Physical Activity
MetS	Metabolic Syndrome
MetSSS	Metabolic Syndrome Severity Score
NAFLD	Non-alcoholic Fatty Liver Disease
NCD	Non-communicable Disease
OWs	Office Workers
PA	Physical Activity
RMSEA	Root Mean Square Error of Approximation
SEM	Structural Equation Modelling
SRMR	Standardised Root Mean Square Residual
TG	Triglycerides
WHPPs	Workplace Health Promotion Programmes
WC	Waist Circumference

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Abstract

Background: Office workers (OWs) are prone to impaired Health-related Quality of Life (HrQoL) and can be more likely to develop cardiovascular risk factors, such as the Metabolic Syndrome (MetS) or Non-alcoholic Fatty Liver Disease (NAFLD) in comparison to other occupational groups. These health impairments are amongst others caused by low levels of physical activity (PA) and unhealthy dietary behaviour (DB). A central health promotion strategy, which has received increasing attention over the last decade also by the World Health Organisation (WHO), concerns health literacy and the domain-specific health literacy facets of physical activity-related health competence (PAHCO) and food literacy (FL). However, these domain-specific health literacy facets have not been addressed in OWs, which is surprising due to the evident health demands in this target group. Moreover, current research on domain-specific health literacy predominantly examined subjective health outcomes in mainly cross-sectional studies. Consequently, this dissertation project addressed these gaps and aimed at achieving these goals for future research (1) by examining the connection of PAHCO and FL with objective cardiovascular risk factors and (2) assessing changes in these domain-specific health literacy facets and its influence on health-related outcomes following an in-person multicomponent workplace health promotion programme (WHPP) in OWs.

Methods: The first and the second study addressed research goal (1) by examining the connection of domain specific health literacy with health behaviour and cardiovascular risk factors. In the first study, the relationships of PAHCO with leisure-time physical activity (LTPA) and MetS was examined while the second study transferred this research goal to FL and its relationship with DB as well as NAFLD. These two studies on domain specific health literacy and the cardiovascular risk factors can be compared to previous studies investigating subjective health outcomes. In addition, the first two studies of this dissertation extended previous research on a methodological level with respect to objectively measured cardiovascular risk factors and by investigating structural equation modelling (SEM) or path analytic approaches. The third and the fourth study focused on research goal (2) by investigating changes in PAHCO and FL and the respective effect on health behaviour and health outcomes following the aforementioned WHPP over a period of 18 months. The third study placed the focus on temporal changes in PAHCO, LTPA and HrQoL, whereas the fourth study targeted FL and DB. These two studies advance prior longitudinal research on domain-specific health literacy, which did not explicitly address OWs and was limited to shorter follow-up periods.

Results: The first study supported research goal (1) by confirming the link between domain specific health literacy and cardiovascular health with PAHCO demonstrating a small to

moderate negative correlation with the MetS. LTPA did not emerge as a relevant mediator in the association between PAHCO and MetS. The second study was partially in line with research goal (1) because FL showed a small to moderate indirect-only relationship between FL and NAFLD mediated by DB. The third and fourth study confirmed research goal (2) and showed substantial and sustainable improvements in PAHCO and FL following a comprehensive three-week WHPP over the course of 18 months. In addition, these studies revealed that PAHCO has a small to moderate positive influence on LTPA and HrQoL, while FL accordingly has a health promoting effect on DB.

Discussion: These findings point towards a health-promoting connection between domain-specific health literacy and cardiovascular risk factors. Within this connection, differences between PAHCO and FL must be taken into account, which could derive from differing conceptualisations of the domain-specific health literacy constructs as well as the susceptibility to external influences on LTPA and DB. Furthermore, this thesis underscores that WHPPs can have a lasting improvement for domain-specific health literacy facets, which in return increase LTPA, DB and HrQoL in OWs. These findings point towards the potential benefits of PAHCO and FL in this target group as well as for the development of WHPP. Yet, future research should examine domain-specific health literacy in randomised controlled study designs and identify the interconnectedness of these facets in a person-oriented approach to comprehend the relevance also for precision prevention approaches in occupational health.

1 Introduction

Non-communicable diseases (NCDs) pose a significant risk to the health and overall well-being of populations worldwide, imposing substantial social, medical, and economic burdens (Mauch et al., 2022). In the adult population, more than 70 % of deaths globally and around 90 % of deaths in Germany are attributed to NCDs (Finlay, 2020; Wang & Wang, 2020). Yet, 40 % of the deaths caused by NCDs are preventable (Melkamu & Jeanne, 2019), which underscores the value of health promotion and the investigation of causes for NCDs. The causes of NCDs are multifactorial and are associated with several health-related indicators, which derive from behavioural, social, environmental and genetic determinants (Budreviciute et al., 2020). On the level of health-related indicators, the metabolic syndrome (MetS) (Simmons et al., 2010), non-alcoholic-fatty liver disease (NAFLD) (Josloff et al., 2022) and impaired health-related quality of life (HrQoL) (Ko et al., 2015; Phyo et al., 2021) are known relevant risk factors for NCDs, which should be targeted by health promotion strategies. Moreover, on the level of behavioural determinants, amongst other health behaviours, PA (Geidl et al., 2020) and DB (Iriti et al., 2020) present major risk factors for these health-related indicators and consequently NCDs.

Besides the importance of targeting these health-related indicators and behavioural determinants in health promotion and prevention of NCDs, social determinants and the social setting, in which these promotional efforts take place, are crucial (Michael & Ruth, 2019; Whitelaw et al., 2001). In the adult population, the workplace setting plays a pivotal role in the implementation and execution of health promotion programmes (Ikhioya, 2018) also because working adults are estimated to dedicate 30 % to 40 % of their waking hours to their occupational work (Loyen et al., 2019). A central target group for workplace health promotion programmes (WHPPs) are office workers (OWs), with an estimated increasing proportion of about 50 % of working adults in Germany (Backé et al., 2019; Hammermann & Voigtländer, 2020). OWs are primarily engaged in desk-based and digitally assisted onsite or remote occupational activities, such as writing emails or giving presentations (Babapour Chafi et al., 2022).

These occupational activities in the office environment are connected to the working environment of OWs, which can diminish HrQoL in this target group (Bjärntoft et al., 2020) and lead to an elevated risk of NAFLD (Lee et al., 2021) and MetS (Strauß et al., 2016). In connection to these risk factors of NCDs, OWs' occupational environment and organisation of work are also linked to behavioural determinants of NCDs as this target group largely displays insufficient levels of PA (Biernat & Piątkowska, 2018) and faces work-related barriers to maintain a healthy DB (Clohessy et al., 2019; Glympi et al., 2020). In addition, promotion of PA and DB in OWs is of particular importance in the workplace as these

behavioural characteristics are directly connected to the health-related indicators of HrQoL, NAFLD and MetS and consequently to NCDs (Chandrasiri et al., 2016; Kolbe-Alexander & Lambert, 2013).

To promote the behavioural determinants of PA and DB with the aim of meliorating risk factors for NCDs, enhancement of domain-specific health literacy facets, namely physical activity-related health competence (PAHCO) and food literacy (FL) present a promising strategy in this target group (Oppermann & Dierks, 2023; Silva, 2023). Although the underlying definitions of this construct are distinct, both domain-specific health literacy facets aim to increase and tailor health-enhancing behaviour on a predominantly personal level to improve health indicators (Krause et al., 2018; Sudeck & Pfeifer, 2016). While current findings underscore the relevance of targeting personal determinants, next to e. g. environmental and genetic determinants to explain health behaviour (Emilien & Hollis, 2017; Rhodes et al., 2019), research on the personal determinants of PAHCO and FL is still in its infancy (Buchmann et al., 2023; Silva, 2023). Since previous studies mainly investigated these domain-specific health literacy facets with behavioural determinants or subjective health-related indicators for NCDs by using observational study designs (Cabezas & Nazar, 2023; Carl, Grüne, et al., 2021; Peñalvo et al., 2021; Schmid et al., 2020), the need for further research on PAHCO and FL becomes particularly evident.

Thus, this dissertation project focuses on existing gaps in current research on PAHCO and FL and thereby examines setting-related benefits of WHPPs within the particular demands for health promotion in OWs. Firstly, the connections of PAHCO and FL with objective health outcomes are crucial to strengthen the rigor of these domain-specific health literacy facets by accounting for, e.g. influences of social desirability (Tempelaar et al., 2020). Secondly, gaining longitudinal insight on the changes of PAHCO and FL and their effect on health and health behaviour following a WHPP presents essential information for the development of effective and potentially tailored interventions towards precision prevention of NCDs (Carl, Grüne, et al., 2021; Friedrich et al., 2023).

Therefore, the present thesis addresses two research objectives in OWs separately for PAHCO and FL by investigating (1) the connection of PAHCO and FL with health behaviour and subjective and objective health outcomes as well as (2) the longitudinal changes of these domain-specific health literacy facets and their effect on health behaviour and health outcomes.

2 Background

This chapter first describes the occupational background and the target group of OWs in general within the conceptual model for protection and promotion of health and safety at the workplace thereby underscoring demands and strategies of health promotion for OWs at the workplace. Then, the chapter will link the conceptual model for protection and promotion of health and safety at the workplace by Sorensen (2016) with the integrative model of health literacy by Sørensen et al. (2012) and highlight the need for the domain-specific facets of PAHCO and FL. Finally, the current research and demands for future research on these domain-specific health literacy facets will be outlined and accordingly the research goals of this thesis for PAHCO and FL will be presented.

2.1 Conceptual Model for Protection and Promotion of Health and Safety in OWs

A review by Goldgruber and Ahrens (2010) on the effectiveness of WHPPs underscored the need for theoretical and model based approaches to explain and promote workers health. Within this claim, the conceptual model by Sorensen (2016) takes a holistic perspective at workers health and safety to inform research and practice on WHPPs. This conceptual model by Sorensen et al. (2016) comprises the determinants of enterprise and worker characteristics, workplace policies, programmes and practices as well as conditions of work and worker proximal outcomes, which are interconnected and ultimately influence workers' health and enterprise outcomes. While, Lecours et al. (2023) note that this conceptual model lacks, e. g. the motivational perspective of implementing integrative prevention and future research on these conceptual models needs valid measurement tools and testing, the integrative model by Sorensen et al. (2016) holds several benefits which are suitable to structure the background of this dissertation project. This integrative model has an interdisciplinary and holistic theory-driven perspective on worksite health protection and health promotion, which can offer guidance for the development of workplace policies, programmes and practices as aimed at by this dissertation project.

Thus, the following section will start by briefly characterising OWs' enterprise and worker characteristics as well as describing conditions of work, which are important contextual factors for worker proximal outcomes and efficient WHPP. In line with the focus of this dissertation project on the personal-level, and more precisely domain-specific health literacy facets, the focus will be shifted to the worker proximal outcomes, worker and enterprise outcomes. Lastly, workplace policies, programmes and practices will be addressed, which are of particular importance due to the target of validating the usefulness of domain-specific health literacy facets for WHPP in OWs (Figure 1).

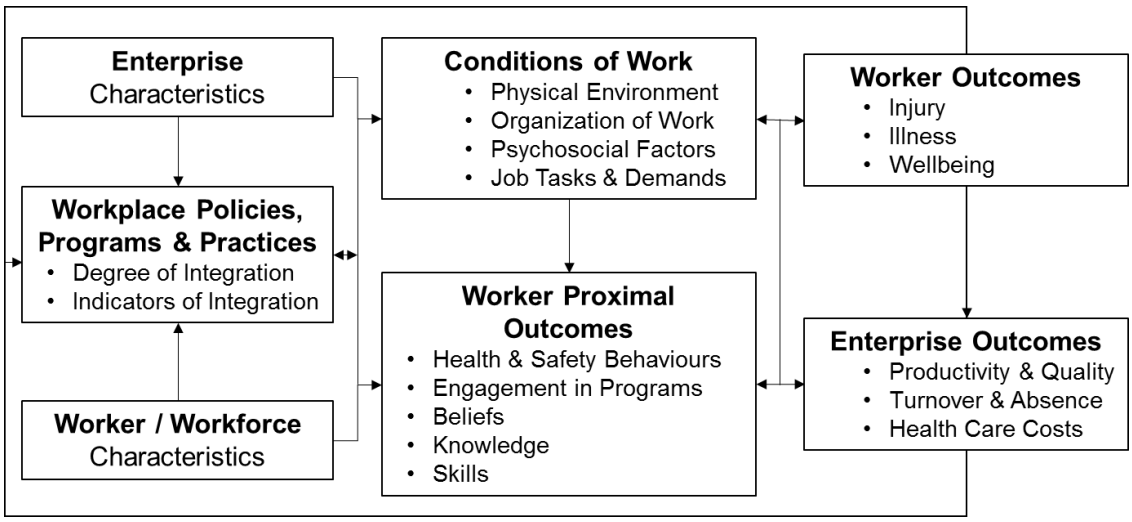

Figure 1. Conceptual Model for Protection and Promotion of Worker Health and Safety by Sorensen et al. (2016)

2.1.1 Enterprise and Office Worker Characteristics

Enterprise characteristics for example consist of a company's size and the salary partially shaping workers resources and access to WHPPs (Sorensen et al., 2016). With respect to these enterprise characteristics, OWs' are predominantly employed at large enterprises mainly in the occupational sectors of financial services and information and communication technology (Hammermann & Stettes, 2023; Statistisches Bundesamt, 2022) and have on average higher salaries compared to other occupational groups, e. g. blue-collar workers (Parui, 2021). The tendency of OWs being employed more frequently at larger enterprises could, in general, facilitate the implementation of WHPPs, because large enterprises in comparison to small and medium enterprises already maintain relevant structures, such as workers' council or safety experts, and are more aware of the external representative meaning of WHPP (Ansmann et al., 2012; Schaefer et al., 2016)

Regarding worker characteristics, such as age, gender, education and ethnicity, OWs in Germany seem relatively evenly distributed across all age and gender groups with deviations depending on the occupational sector or the company characteristics (Hammermann & Stettes, 2023; Janwantanakul et al., 2012). In addition, OWs are more likely to report a higher educational background (Azevedo et al., 2021) and show a smaller variance with respect to their ethnical background in comparison to blue-collar workers (Ryu et al., 2017; Wilson & Maume, 2014). The enterprise and worker characteristics of OWs indicate that implementation of WHPPs might be facilitated by the financial and educational prerequisites of this target group (der Meer et al., 2024) and more likely face barriers of age-specific or job-specific targeting (Duman & Yurtseven, 2021).

2.1.2 Conditions of Office Work

Conditions of office work consist of job tasks/demands, psychosocial factors, physical work environment and organisation of work, which are determined by the worker and enterprise characteristics and influence worker and enterprise outcomes (Sorensen et al., 2016). Due to the comprehensive scope of the conceptual model, this chapter will highlight only selected factors of this model, which are of specific value regarding PA, DB and health in the occupational group of OWs.

Job tasks and organisation of office work can vary widely depending on the enterprise and workers' characteristics or specific sectors and job roles. In general, however, office work is organised by fulfilling administrative, preparatory and communicational job tasks (e.g. managing emails, scheduling appointments or creating documents) utilizing computers, which often involves software or sector-specific tools (Babapour Chafi et al., 2022). With respect to the communicational job tasks, OWs collaborate by using direct verbal, email, instant messaging or video conference-based communication with colleagues and people outside the organisation, which indicates the importance of teamwork and communication skills in OWs (Miller, 2014).

Furthermore, also due to the cognitive nature and flexible work processes (Dhungel et al., 2021), office work is prone to job demands of heavy work investment, e. g. long working hours and overtime (Lohmann-Haislah et al., 2022), and work intensification, such as skipping breaks (Vieten et al., 2023). Recent studies suggest various determinants for heavy work investment and work intensification in OWs ranging from personal psychosocial factors, such as personal motivation and organisational commitment (Bjärntoft et al., 2020) to colleague peer pressure or supervisors' expectations (Zhang & Seo, 2018). Dhungel et al. (2021) suggest that these job demands and psychosocial factors might occur more frequently in OWs in comparison to blue-collar occupations. Current literature also connects these facets of conditions of office work to low levels of PA (Landais et al., 2022), unhealthy DB (Lee et al., 2021) and consequently to risk factors for NCDs (Wong et al., 2019).

In addition, OWs' organisation of work has evolved due to digitally driven changes in the organisation of office work (Vuori et al., 2019). These changes are encapsulated under the term "new ways of working" and can be described by the facets of time- and location-independent work, autonomous management of performance, free access to organisational knowledge and flexibility in working relations (Gerards et al., 2018). These facets can be connected to psychosocial factors in OWs, such as work-privacy conflicts, and are also related to low levels of PA (Wilms et al., 2022) and changes to DB (Bartmann et al., 2023). In addition, remote work is positively linked to the psychosocial factors of organisational commitment, but also shows an association with work intensification (Felstead & Henseke, 2017). This connection to work intensification implies longer working hours in OWs, which

in return might impair health behaviour and health outcomes (Mauno et al., 2023; Prasad & Satyaprasad, 2023).

Concerning the physical environment of OWs, this occupation is characterised by the office or remote working environment, which can influence job tasks and present a job resource as well as a job demand, and consists of factors such as, workstation layout and controls, greenery, noise and light (Richardson et al., 2017). The review of Colenberg et al. (2021) concludes that the office environment and the layout of the workstation can nudge physically active and healthy dietary behaviour by creating attractive, obvious and easy opportunities for health-enhancing behaviour and thereby increase HrQoL and other risk factors for NCDs. Next to this example of a health promoting office environment, the office environment might also have impairing effects on health behaviour and HrQoL, e.g. when too many occupants are sharing the workspace (Shafiee Motlagh et al., 2018).

2.1.3 Office Worker Proximal Outcomes

The connection between conditions of work and proximal outcomes in OWs was already indicated in the aforementioned chapter. Due to the relatively low prevalence rates of OWs' safety incidents and occupational injuries (Won et al., 2007), this chapter will focus on the current research on health behaviours, as well as beliefs, knowledge, skills and engagement in WHPPs in this occupation. Besides other health behaviours, such as sedentariness (Huang et al., 2019), PA and DB are crucial components of WHPPs, because these health behaviours are considered highly modifiable (Commissaris et al., 2016; Geaney et al., 2013), interconnected (Heiland et al., 2021; Shimura et al., 2020) and affect global and individual outcomes (Lusa et al., 2020; Rachmah et al., 2022).

Concerning PA, Biernat and Piatkowska (2020) highlight that over the last decade, around 50 % of OWs over the last decade met the World Health Organisation's (WHO) recommendation of at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity (PA) per week. Furthermore, compared to other occupational groups, OWs exhibit lower levels of light and moderate PA and tend to accumulate more sedentary time (Prince et al., 2019). Additionally, OWs do not compensate for their high work-related sedentary time by engaging in longer periods of LTPA (Clemes et al., 2014), thereby increasing the risk of diminished HrQoL and MetS (Browne et al., 2017). With respect to the connection between sedentariness and PA, Prince et al. (2021) postulate that leisure-time PA (LTPA) in sedentary and inactive occupations, such as office work, has an especially health-enhancing effect on the risk of developing NCDs compared to more active occupations. While this finding, on the one hand, highlights the importance of tailored WHPPs concerning different occupations, it underlines, on the other hand, a qualitative targeted focus on PA in health promotion. This is especially important as occupational PA, unlike LTPA, does not demonstrate a positive relationship with the risk for NCDs and may

even show an inverse relationship (Holtermann et al., 2021). Therefore, addressing health-enhancing PA, which encompasses all forms of PA that contribute to health benefits without causing undue harm or risk, is a fundamental task for WHPPs in the target group of OWs (Whiting et al., 2021).

Regarding DB, Richter et al. (2021) found that only about 55 % of female and less than 30 % of male German working-age adults with similar sociodemographic characteristics compared to OWs reported daily fruit and vegetable consumption, which did not comply with the official WHO recommendation of five portions of fruit and vegetable intake per day (Pem & Jeewon, 2015). Although this recommendation for DB is less frequently fulfilled (Richter et al., 2021) in comparison to other health behaviours, OWs show better DB than other occupational groups, such as blue-collar workers in a Spanish national survey (Ronda-Pérez et al., 2020). Nevertheless, OWs also have to face barriers for adopting healthy DB, which often stem from factors such as workplace stress, time pressures, a scarcity of food options, and societal influences that promote the consumption of unhealthy foods (Clohessy et al., 2019). In addition to the outlined behaviour and the barriers for healthy DB, OWs' exposure to inactive and sedentary workplace characteristics in combination with DB contributes to the "energy gap" in this occupation (Hill et al., 2009). The term "energy gap" describes the interplay between heightened energy intake and reduced energy expenditure to achieve different body weight outcomes in individuals and populations, culminating in impaired HrQoL and an elevated prevalence rate of MetS, NAFLD and consequently NCDs (Wagner & Brath, 2012).

With respect to beliefs, knowledge, skills and engagement in WHPPs, the target group of OWs assigns great value to beliefs concerning PA, but also shows lacking awareness of the importance of PA in connection with other risk factors, such as sedentariness (Landais et al., 2022). Furthermore, health beliefs concerning DB in general seem to be of high relevance for OWs, yet in particular dietary health beliefs with a social barrier, such as enjoying unhealthy snacks in a group to boost the team spirit are deeply manifested in this group without reflecting on the potential consequences for their health (Walker, 2023). These studies indicate that health is acknowledged as important by OWs. However, there are instances where social and work-related beliefs, take precedence and influence health beliefs and behaviours (Landais et al., 2022). Knowledge on PA in working age adults was in general very limited, but OWs compared to other occupations showed a slightly higher percentage of knowing about PA recommendations (Knox et al., 2015). Knowledge on healthy DB in working aged adults is also poor, with an Australian study indicating only about 24 % of this group displaying adequate knowledge for example on fruit and vegetable consumption (Hill et al., 2020). Yet, knowledge on healthy DB might be slightly higher in OWs because educational and socioeconomic status, which are usually higher in this

occupation, are positively connected with DB knowledge (Ikemoto et al., 2019). Although research on PA and DB-related skills is rare, skills on these health behaviours seem to be at a moderate level in the working age adults as well as for OWs (Murakami et al., 2022; Pieczyńska et al., 2019). With respect to the engagement in WHPPs, OWs' elevated social standing, advanced education, increased income, and consequently, enhanced overall health beliefs, might significantly contribute to the more frequent implementation and participation of well-being programmes for this particular group of employees (Hyży et al., 2023) also in comparison to other groups, such as blue-collar workers (van der Feltz et al., 2022).

2.1.4 Office Workers' Health Outcomes

The previous chapters characterised OWs' conditions of work and proximal health outcomes in particular concerning PA and DB and pointed towards potential consequences for OWs' health outcomes. This chapter will expand on these health outcomes and thereby place the focus on HrQoL, MetS and NAFLD, which are risk factors for NCDs and can be viewed as proxy parameters for the illness facet in the Sorensen model (Sorensen et al., 2016). Injuries will not be addressed because of relatively low prevalence rates of injury-related diseases in OW as compared to other occupations (Morrissey et al., 2023).

HrQoL comprises the functioning of individuals in their life and the perceived well-being in physical, mental, and social domains of health (Karimi & Brazier, 2016). OWs in comparison to blue-collar workers show no differences in HrQoL in a Japanese national survey with the majority of workers in either group reporting good to acceptable HrQoL (Kayaba et al., 2021). A Chinese meta-analysis found equal levels of HrQoL between different occupational groups compared to OWs and stated that among the determinants regarding working conditions, a lack of PA during long working hours can substantially impair HrQoL, which is a common theme for OWs (Su et al., 2021). Furthermore, facets of unhealthy DB, such as a lack of adherence to specific diets (Katcher et al., 2010) or eating while doing another activity (Beresford et al., 2012), were connected to diminished HrQoL. Regarding the working conditions of OWs with a high potential for inactive activities and work intensification, such a connection between health behaviour and HrQoL seems plausible. These findings underscore the importance of PA and DB in relation to self-reported health and the prevention of NCDs consequently. Yet, some studies suggest that objective health outcomes could mediate this relationship as these outcomes are affected by PA and DB and in return influence HrQoL in working aged adults (Beresford et al., 2012; Marcos-Delgado et al., 2020).

One objective health outcome with particular relevance for OWs might be MetS, which is a cluster of metabolic abnormalities including abdominal obesity, high blood pressure, impaired fasting glucose, high triglyceride levels, and low HDL cholesterol levels (Lemieux

& Després, 2020). The particular relevance of MetS arises from findings by Strauß et al. (2016) who found higher prevalence rates for MetS in this occupational group in comparison to fire fighters in a German cross-sectional study. However, a systematic review revealed mixed evidence concerning the prevalence of MetS and occupation with large variation between occupations in different countries (Strauss et al., 2022). A meta-analysis by Prince et al. (2019) found increased waist-to-hip ratio in OWs', which is connected to MetS (Alzeidan et al., 2020), but not in other MetS indicators such as elevated blood glucose or lipids. While these studies to some extent confirm the specific need for WHPPs targeting MetS in OWs, the current state of research uniformly addresses the relevance of PA and DB to mitigate the burden of this disease both in the general population and in OWs (Alavi et al., 2015; Lee et al., 2015; Ryu et al., 2017). Targeting these health behaviours presents a particularly fitting strategy due to the high prevalence of inactive OWs and their barriers for healthy DB in the working context.

Lastly, NAFLD describes the accumulation of excess fat in the liver (steatosis), which is distinct from other recognised causes of steatosis, such as alcohol consumption, viral infections, drug-induced effects or autoimmune disorders (Radu et al., 2023). NAFLD and MetS are cyclically connected, as both can be cause or symptom for the other (Hashimoto et al., 2015). Although research on NAFLD in different occupations is still limited (Riazi et al., 2022), Gupta et al. (2022) found higher prevalence rates of NAFLD in OWs compared to other occupations in a cross-sectional study of Indian working aged adults. Next to these tentative findings on the prevalence of NAFLD in OWs, the predictive quality of PA and DB for the prevention of NALFD in working aged adults is well established, which suggests these health behaviours as viable targets for WHPPs also in OWs (Tsunoda et al., 2021; Zhang et al., 2019). Targeting these health behaviours in this occupation can be of particular importance, because long working hours and sedentariness present additional distinct risk factors for NAFLD, which are a common occupational trait of OWs and are interconnected with PA and DB (Song et al., 2021; Zhang et al., 2019).

2.1.5 Outcomes of Office Work Enterprises

Although examining the exact costs of impaired HrQoL (Neumeier et al., 2020), MetS (Catalina-Romero et al., 2019) and NAFLD (Targher et al., 2021) on the gross domestic product is complex, these risk factors for NCDs lead to a substantial increase in sickness absence and presenteeism (Finkelstein et al., 2021). Due to the economic burden resulting from lost productivity and social security payments, sickness absence and presenteeism are relevant enterprise outcomes (Stuart, 2001).

Concerning sickness absence, other occupations in comparison to OWs display higher prevalence rates due to musculoskeletal disorders, but show comparable rates of sickness absence due to mental disorders (Blomgren & Jäppinen, 2021). Furthermore,

Norder et al. (2015) found that in comparison to other occupations, OWs during mental sickness absence, which is connected to HrQoL, need longer time periods to recover from this absence. Current research examines physical work environment (Nielsen & Knardahl, 2020), proximal worker outcomes, such as PA (Drake et al., 2020) and DB (Fitzgerald et al., 2016) and risk factors for NCDs (Hoang et al., 2023) as essential determinants of sickness absence in OWs. These studies underline the importance for WHPPs to target OWs' proximal outcomes of PA and DB to reduce the burden of sickness absence.

Besides sickness absence, sickness presentism is a crucial enterprise outcome, which is described as continuing to attend work during illness and hampers enterprise productivity (Kinman, 2019). While a meta-analysis by Miraglia and Johns (2016) examines a positive connection between sickness absence and sickness presentism, current research finds no differences in sickness presentism prevalence rates for OWs in comparison to other occupations with an overall prevalence ranging at a high level between 40-70 % (Park et al., 2020). Similar to sickness absence, studies with OWs, however suggest preventive connections between sickness presentism and the health behaviours of PA (Hervieux et al., 2023) and DB (Tsuchida et al., 2023) as well as HrQoL (Bergström et al., 2009). These findings further highlight the importance to focus on promoting health behaviours, particularly PA and DB, and health-related risk factors to mitigate the risk of sickness presentism in OWs.

2.1.6 Workplace Policies, Programmes & Practices for OWs

The proximal and enterprise outcomes in the occupation of OWs underscore the need for developing workplace policies, programmes and practices on PA and DB to ameliorate the risk for NCDs. Within these aspects, WHPPs are a central pillar of occupational health and safety management along with return-to-work and occupational safety measures (Klenke, 2018). Furthermore, the conceptual model by Sorensen et al. (2016) states the importance of participatory and comprehensive WHPPs including leadership commitment, coordinated efforts and comprehensive programme content. Besides these general aspects of WHPPs and regarding the specific aim of mitigating the risk of NCDs in OWs, Ryu et al. (2017) evaluate a programme for this target group to prevent MetS, which in a comprehensive approach compares different WHPPs on PA and DB. While other studies emphasise the general relevance of addressing these health behaviours to prevent risk factors for NCDs in OWs (Alavi et al., 2015; Rahma et al., 2021), that particular study reveals a positive effect for a targeted intervention containing the proximal worker outcomes of knowledge, beliefs and skills on PA and DB (Ryu et al., 2017). A review on dietary WHPPs to reduce the risk of MetS risk in the working population highlights these findings and postulates that WHPPs with the strongest effect on DB and indicators of MetS, among other components, directly target behaviour-related knowledge, beliefs and skills. The

importance of these personal factors for PA and DB over environmental and social factors is also highlighted by reviews on these health behaviours in the general population, which report, that personal factors of PA and DB account for the largest of amount of variance explained in these health behaviours (Emilien & Hollis, 2017; Rhodes et al., 2019).

Besides the importance of addressing knowledge, beliefs and skills in OWs to mitigate NCDs, this target group could in particular benefit from WHPPs as OWs display the worker characteristic of higher educational levels. Also with respect to the conditions of work, OWs tend to have a more flexible work schedule in comparison to other occupations, such as blue-collar workers (Azevedo et al., 2021; Bjärntoft et al., 2020; Golden, 2001). OWs' educational background might be beneficial for the implementation of WHPPs, because workers with higher educational levels are more likely to participate in WHPPs also with respect to personal factors as programme determinants (Sponselee et al., 2022). Furthermore, the predominantly flexible work schedule of OWs implies a higher potential to generally incorporate WHPPs during their work schedule, which could function as another facilitator for the implementation of WHPPs (Kaveh et al., 2021).

2.2 OWs' Health Promotion in the Integrative Health Literacy Model

These personal factors of knowledge, beliefs and skills, e.g. for PA and DB, from the conceptual model on Workers Health and Safety by Sorensen et al. (2016) are also embedded in the Integrative Health Literacy Model by Sørensen et al. (2012). Although, a review by Malloy-Weir (2016) examined a total of 250 different health literacy definitions, this health literacy model tried to combine existing health literacy definitions and frameworks and aims to guide research and practice on health literacy to effectively promote health, which underscores the relevance of this model also for this PhD project. Whereas "knowledge" can be found in both models, the integrative health literacy model postulates "competence" instead of the term "skill" and "motivation" in place of "beliefs" (Sorensen et al., 2016; Sørensen et al., 2012). Yet, these deviating terms are also used in other health literacy definitions of several included publications in the review by Sørensen et al. (2012) (Parker, 2000; Zarcadoolas et al., 2003), which confirms the alignment of the terms used and of both models in general. Besides these slight terminological deviations for the personal factors, both models describe social, personal and environmental determinants and the respective influence of these factors on health literacy, which in return affects health behaviour and health outcomes (Sorensen et al., 2016; Sørensen et al., 2012). Furthermore, Sørensen et al. (2012) extend the scope beyond health behaviour and outcomes to other consequences resulting from these personal factors, such as health service use and health costs (Figure 2).

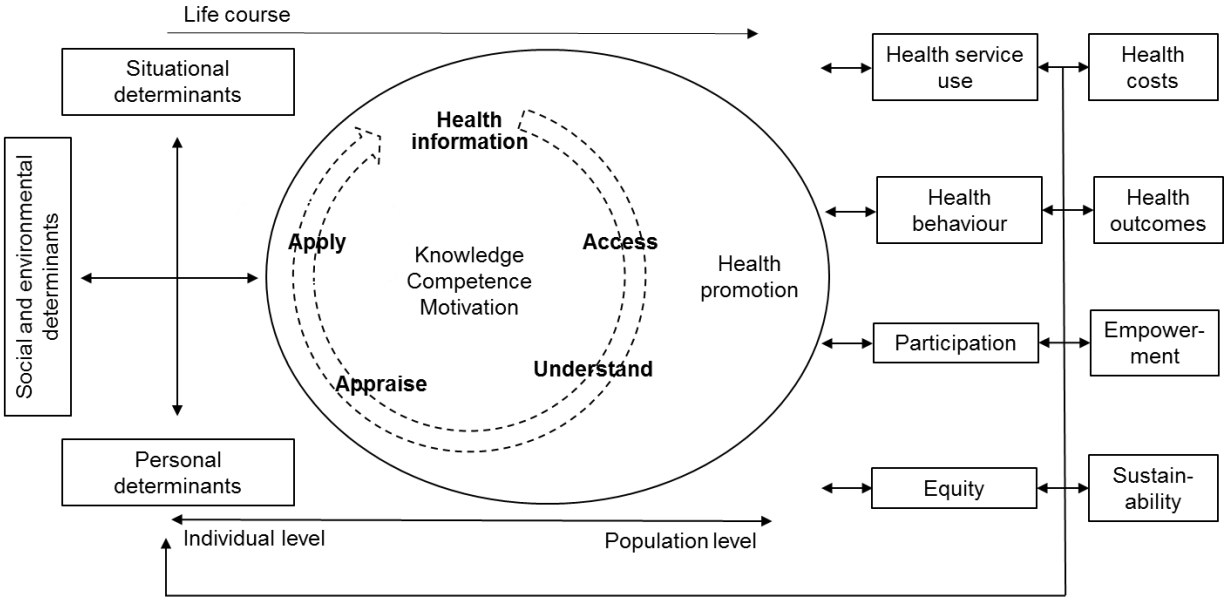

Figure 2. Integrative Model of Health Literacy by Sørensen et al. (2012) Showing only the Context of Health Promotion

In addition, this model integrates the personal factors and existing definitions within the construct of health literacy and proposes an integrative definition from an individual as well as from a public health perspective among others for health promotion. According to the integrative review by Sørensen et al. (2012, p. 3) “health literacy is linked to literacy and entails people's knowledge, motivation and competences to access, understand, appraise, and apply health information in order to make judgments and take decisions in everyday life concerning (…) health promotion to maintain or improve quality of life during the life course”. In this definition and the underlying integrative model, the competencies of accessing, understanding, appraising and applying health information generate knowledge and motivation for health care, disease prevention and health promotion (Sørensen et al., 2012). Furthermore, in the context of health promotion, the integrative model by Sørensen et al. (2012) points out the value of health literacy to change health behaviour and in return health outcomes at the workplace and therefore also for OWs.

A Danish population survey confirms the relationship of health literacy to the health behaviours of PA and DB in Danish working aged adults by mediating 20 % and respectively 13 % of the variance between the relationship of educational level and these health behaviours as well as showing small to moderate effect sizes for the mediation model (Friis et al., 2016). In line with these findings on the connection of health literacy and health behaviour, Ishikawa et al. (2008) examined small effect sizes for the direct connection between health literacy and PA, which was supported by a current review (Buja et al., 2020).

With respect to the connection of health literacy and health outcomes, in a cross-sectional study on OWs from the financial sector Lindert et al. (2023) found a small to moderate indirect as well as direct connection between health literacy and OWs' HrQoL, which was also mediated by the perceived leadership and the organisational health literacy. Furthermore, health literacy showed a small connection with MetS in a cross-sectional study on German working aged adults with age, education and gender additionally explaining this connection (Tajdar et al., 2022). The authors of this study also mention the importance of health literacy to guide and to promote PA and DB in order to mitigate the risk of MetS, which was empirically confirmed by Froze et al. (2018) in a cross-sectional study on health literacy, PA and DB as well as aspects of MetS in Malaysian working aged adults including OWs. Lastly, there exist a need for future research regarding the connection of health literacy with the closely related NCDs risk factor of NAFLD, (Cheng et al., 2018). Moreover, current studies point to a small health promoting connection between health literacy and NAFLD (Nguyen et al., 2021; Subhani et al., 2018) also in OWs (Talebi & Taheri, 2022).

Although health literacy shows a positive connection to PA and DB and displays a health promoting effect to the health outcomes included in this dissertation, OWs are rarely addressed in the studies examining health literacy and the aforementioned NCDs risk factors. This is surprising in view of the relevance of NCDs risk factors in OWs (Strauß et al., 2016; Strauss et al., 2022). Furthermore, the effect sizes of these connections are small to moderate at best, in particular for health literacy and PA as well as DB, which partially might be due to the low level of incorporation of these health behaviours in the general health literacy construct (Carl, Sudeck, et al., 2020; Velardo, 2015). In line with this argumentation, the conceptual review by Sørensen et al. (2012) postulates the importance of specific health literacy skills, which next to application of general literacy and numerical skills are necessary to process domain-specific health information in order to lead a physically active lifestyle and achieve or maintain a healthy diet. While one might assume that general literacy and numerical skills are mostly adequate in OWs due to their educational background, the proximal health outcomes of OWs might indicate that the domain-specific health literacy aspects of PA and DB need improvement.

2.3 Relevance of Domain-specific Health Literacy

The practical need for domain-specific health literacy constructs becomes evident from the current literature with a myriad of different facets from digital (Yang et al., 2022), to mental (Furnham & Swami, 2018), work-related (Ehmann et al., 2021), vaccine (Badua et al., 2022), organisational (Farmanova et al., 2018) or environmental health literacy (Lindsey et al., 2021) that have emerged over the last decades. To describe these different facets of health literacy Atanasova and Kamin (2022) propose that there exist different dimensions, levels and domains of health literacy.

The dimensions are in agreement with Sørensen et al. (2012) and consist of accessing, understanding, appraising and applying health information to make a health-enhancing decision. The different levels are also embedded in the integrative conceptual health literacy model by Sørensen et al. (2012) and consider personal, population or organisational levels to promote health behaviour and health (Atanasova & Kamin, 2022). Currently most health literacy facets comprise predominantly a personal level, such as digital health literacy (Busse et al., 2022) with other facets, e. g. organisational health literacy (Farmanova et al., 2018), being rarely employed as an approach to health promotion. Lastly, in line with Sørensen et al. (2012), the domains are divided in healthcare, disease prevention, and health promotion, with this dissertation project addressing only the later dimension by focusing on WHPPs. Furthermore, domains of health literacy can be segmented into various contexts, fields, topics, or specific diseases (Atanasova & Kamin, 2022). This segmentation could for instance address health literacy facets in the general domain of health promotion with respect to the health behaviours of DB and PA on the individual level and the workplace context.

Developing and investigating domain-specific health literacy facets are important for three mutually dependent reasons (Atanasova & Kamin, 2022; Jorm, 2015; Pinheiro, 2021). First, domain-specific health literacy can draw attention to a neglected or underrepresented field (Jorm, 2015). For instance in PA, domain-specific health literacy could serve to highlight the importance of qualitative health-enhancing aspects of PA, next to focusing on the amount of PA and additionally examine the necessary knowledge, motivation and competencies to lead a physically active and healthy life (Carl, Sudeck, et al., 2020; Warburton & Bredin, 2016). Secondly, domain-specific health literacy can affect policies on health and health behaviour by facilitating health communication, e.g. between experts of WHPP and employees, and thereby increase the effectiveness of existing practices (Jorm, 2015). For the health behaviour of DB, this might be even more crucial in the digital era with misinformation on DB swiftly disseminating via social media (Diekman et al., 2023). Collaborations among WHPP experts and policymakers are essential to build domain-specific health literacy addressing DB to tackle these issues, for example by increasing knowledge and competence to appraise reliable information on food and nutrition (Silva et al., 2023). Lastly, in comparison to general health literacy, domain-specific health literacy can provide valuable insight for the development of interventions (Jorm, 2015). For instance in PA promotion, domain-specific health literacy, e.g. within an baseline assessment, will yield implications on the level of knowledge, motivation and competence of the target group, to inform the intervention development resulting in a potentially higher effectiveness (Carl, Sudeck, et al., 2020).

2.4 Physical Activity-related Health Competence (PAHCO)

Domain-specific health literacy to promote health-enhancing PA is implemented in the "Global Action Plan on Physical Activity 2018–2030" of the WHO (2019), which underlines the value of physical and health literacies and competencies to promote physically active and healthy lifestyles to prevent NCDs. Nonetheless, many of these constructs on physical and health literacies or competencies fail to fully harness their potential because of the distinct conceptualisation of health and physical activity, which do not equally represent significant interactive components (Cairney et al., 2019; Haible et al., 2020).

2.4.1 PAHCO and its Underlying Characteristics

PAHCO resides at the intersection of physical literacy and health literacy and places an equal focus on PA and health (Sudeck et al., 2013; Sudeck & Pfeifer, 2016). This model, which is developed from the structurally comparable general health literacy model by Soellner et al. (2009) and Lenartz (2012), proposes that PAHCO improves health by increasing the amount of PA and shaping PA to have a lasting health-promoting impact on individuals over the lifespan (Carl, Sudeck, et al., 2020; Sudeck & Pfeifer, 2016). To promote health-enhancing PA, PAHCO revolves around three connected sub-competencies, which in return are modelled by underlying basic elements (Sudeck & Pfeifer, 2016)(Figure 3).

The first sub-competence, movement competence (MC), encompasses the motor-related requirements necessary for individuals to engage in planned exercise (e.g., cycling and swimming) and to carry out daily tasks (e.g., lifting heavy objects) (Carl, Sudeck, et al., 2020). Secondly, control competence ensures that physical activity contributes to health improvements and is subdivided into a physical aspect, involving the ability to apply appropriate load and intensity (control competence for physical training - CCPT), and a psychological aspect for mental health benefits (PA-specific affect regulation; PAAR) (Haible et al., 2020). Thirdly, PA-specific self-regulation (PASR) encompasses psychological dispositions and motivational-volitional elements aimed at ensuring consistent engagement in PA (Sudeck et al., 2018). Consequently, these three sub-competencies result from the combination of basic elements for PA (Carl, Sudeck, et al., 2021). Movement competence is formed by motor abilities, motor skills, and awareness of movement and body (such as endurance, strength, and balance). Control competence depends on individuals' understanding of action and effect knowledge of PA to organise subsequent exercise in accordance with desired health outcomes. PASR comprises the basic elements of self-efficacy, beneficial motivational structures, and positive attitudes towards health-enhancing PA (Sudeck & Pfeifer, 2016).

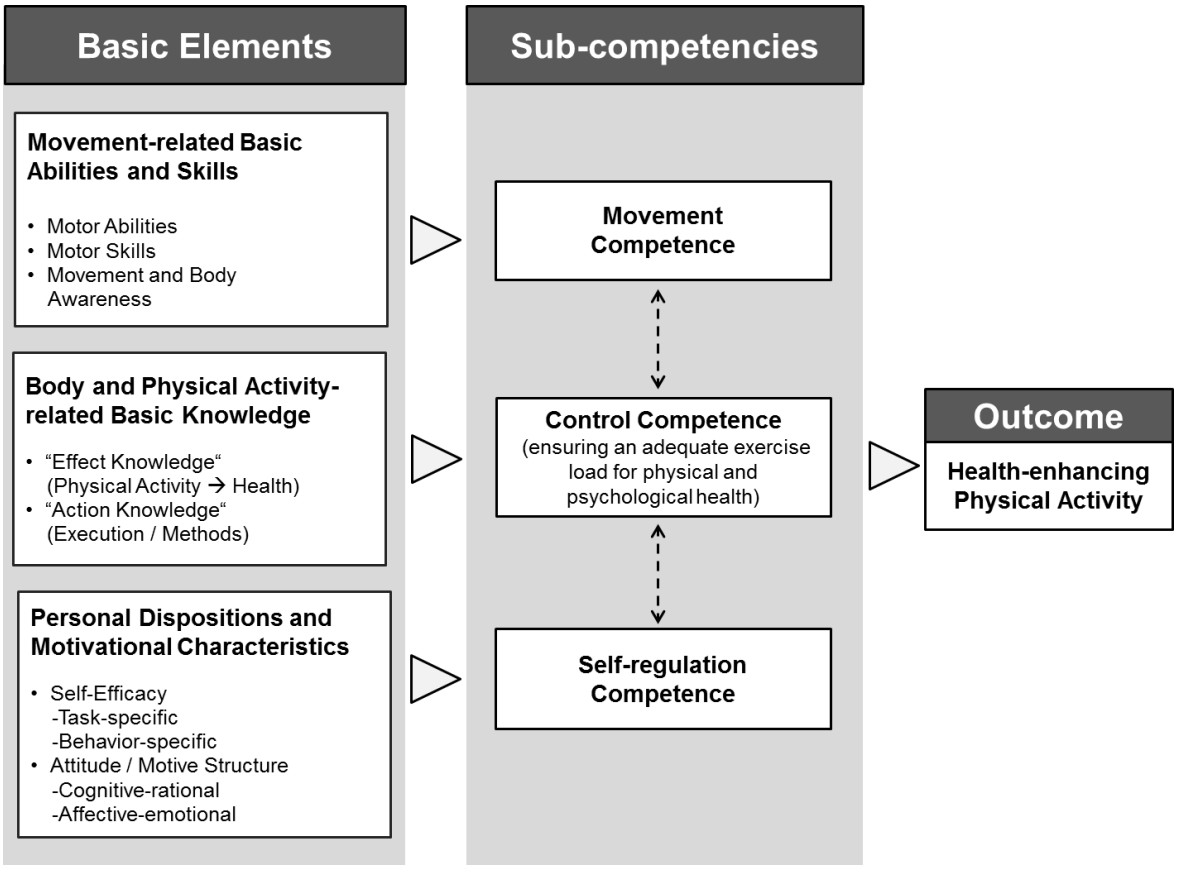

Figure 3. Physical Activity-related Health Competence Model by Sudeck and Pfeifer (2016)

Along with the basic elements and sub-competencies encouraging health-enhancing PA, PAHCO is considered to inherit the qualities of a personality trait (Carl, Sudeck, et al., 2020). In accordance with contemporary theories on personality traits (Roberts et al., 2017) and competence research within educational sciences (Wiek et al., 2011), PAHCO is believed to exhibit changeability and relative temporal stability, allowing for sustainable promotion through structured interventions (Carl, Grüne, et al., 2021). Such interventions should target one or ideally, multiple basic elements to promote the sub-competencies outlined in the PAHCO model (Carl, Sudeck, et al., 2020). The potential to promote and sustain PAHCO through interventions holds promise for lasting promotion of health-enhancing PA and consequently mitigate risk factors for NCDs (Carl, Grüne, et al., 2021).

2.4.2 Current Research on PAHCO, PA and Health in WHPPs

The above-mentioned theoretical connection between PAHCO and indicators of health-enhancing PA is affirmed by multiple cross-sectional studies on health promotion in adult participants including apprentices in nursing as well as automotive mechatronics (Carl, Grüne, et al., 2020) and employees of Swiss companies (Schorno et al., 2021). Most of these studies revealed moderate positive connections between PAHCO and PA, which is in accordance with findings of a German population-representative survey in adults by Carl et al. (2024). On a sub-competence level, PASR followed by CCPT emerge as the sub-

competencies with the most substantial positive connection to PA by displaying moderate to strong effect sizes (Carl et al., 2024; Sudeck & Pfeifer, 2016). PASR might show the strongest connection to PA because PASR is connected to setting behaviour change plans and troubleshooting, which consequently enhances individuals' capacity to translate their PA-specific intentions into planned PA behaviour (Schorno et al., 2022).

Moreover, the PAHCO model also suggests a theoretical connection to health indicators, which has also been investigated mainly by observational study designs. The population representative study in German adults supports this connection by showing a strong positive effect between PAHCO and HrQoL (Carl et al., 2024). In line with these results, apprentices in nursing and automotive mechatronics exhibited a positive moderate to strong correlation between PAHCO sub-competencies and HrQoL (Carl, Grüne, et al., 2020). Among the sub-competencies, MC shows the strongest connection to HrQoL (Carl, Grüne, et al., 2020; Sudeck & Pfeifer, 2016), but the other sub-competencies displayed consistent positive connections as well, e.g. in a population representative study in German adults (Carl et al., 2024). MC might be of particular relevance as this sub-competence could function as a gatekeeper for participation in health-enhancing PA, which consequently affects health (Carl, Sudeck, et al., 2021).

With respect to longitudinal research on the connection of PAHCO and health promotion, Schmid et al. (2020) examined that profiles of PAHCO, and changes in these profiles, are positively connected to aspects of HrQoL over a period of four months. Furthermore, this study revealed that PAHCO profiles remained relatively stable between the two data collection phases, which supports the authors' assumptions of time-stable PAHCO sub-competencies in a non-interventional design (Carl, Sudeck, et al., 2020; Schmid et al., 2020). Concerning intervention studies on PAHCO in health promotion, Schorno et al. (2022) investigated the effectiveness of a PA counselling programme in Swiss employees and found that PASR as well as PA could be sustainably increased by the PA counselling sessions in a follow-up assessment after three months. Furthermore, Oppermann and Dierks (2024) recently published a preprint pilot study, which stated a small positive effect on PAHCO following a digital WHPP aiming at the enhancement of PA in OWs over a period of three months.

While current longitudinal research on the connection of PAHCO with PA or health in health promotion with working aged adults is limited (Schmid et al., 2020), interventional studies on PAHCO in an educational school context show mixed findings regarding changeability and temporal stability of PAHCO over a period of four months (Rosenstiel et al., 2021; Volk et al., 2021). However, next to research specifically targeting PAHCO, previous research separately addressed the basic elements of this construct, as for example a review by Knittle et al. (2018) examined a promotion of motivation for PA also

by WHPPs. Yet this dissertation project focused on the domain-specific health literacy facet of PAHCO, which holds the advantage of coupling the basic elements for PA.

2.4.3 Demand for Future Research on PAHCO in OWs' Health Promotion

Previous research on PAHCO and health promotion mainly employs subjective indicators for health and PA (Schmid et al., 2020). This notion is important, because subjective indicators for health and PA hold the risk of self-report bias and usually are of lower accuracy in comparison to objective measures, for example in the prediction of NCDs (Bauhoff, 2011; Soewondo et al., 2010). This inclusion of objective health outcomes has multiple benefits for future research by, on the one hand, fostering the validity of the respective construct (Helmerhorst et al., 2012), and on the other hand, by helping to bridge gaps in health promotion research between research disciplines as well as health promotion practice (Glasgow et al., 2004). The findings of previous research on PAHCO, PA and health might be transferable to OWs, for example concerning the connection of PAHCO and HrQoL in apprentices (Carl, Grüne, et al., 2020). However, including objective health outcomes in future research would help to illuminate the potential impact of PAHCO in the prevention of NCDs in this target group due to the close connections of objective risk factors, such as MetS, with NCDs and the relatively high risk for NCDs in OWs (Strauß et al., 2016; Strauss et al., 2022).

In addition, most of the current studies on PAHCO, PA and health in working adults are currently observational (Carl et al., 2024; Carl, Grüne, et al., 2020; Carl, Sudeck, et al., 2020; Schorno et al., 2021; Sudeck & Pfeifer, 2016). Therefore, the findings remain to some degree speculative (Carl, Grüne, et al., 2021), because causal inferences cannot be drawn based on the employed study design of most research in this area. This evidence basis underscores the demand for longitudinal research to gain more insight into the connections and the effects of PAHCO on PA and health (Carl, Grüne, et al., 2021; Glass et al., 2013). In addition to the general need for longitudinal research, none of the existing longitudinal studies examine longer follow-up periods beyond six months (e. g. Rosenstiel et al., 2021; Volk et al., 2021). Employing longer follow-up periods is important as intervention effects can diminish rapidly over time and the theoretically claimed temporal stability of PAHCO has not thoroughly been investigated following an intervention for working aged adults by previous studies beyond the period of six months (Kwasnicka et al., 2016). Sustainable changes in PAHCO also beyond the period of six months might confirm the potential of lasting benefits for PA and health derived from PAHCO (Carl, Grüne, et al., 2021) and underscore its value in the development of WHPPs.

2.5 Introducing Food Literacy (FL)

Along with PAHCO as the domain-specific health literacy facet of health-enhancing PA on the behavioural level, the domain-specific healthy literacy facet of healthy DB is represented by food literacy (FL) (Krause et al., 2018). While this construct was first scholarly mentioned in published literature in 2001 (Kolasa et al., 2001), a plethora of differing definitions and conceptualisations have led to a lacking consistency in FL research and partially limited the synthesis of findings (Thompson et al., 2021). Yet, the construct has gained popularity in the last decade in health promotion research (Yuen Eva et al., 2018) with the aspect of food-related skills and knowledge being also incorporated within the WHO's (2019) recommendations on healthy diets addressing adults at the workplace amongst other target groups.

2.5.1 Describing the Construct of FL

Within differing conceptualisations, the FL definition and operationalisation, employed in this dissertation project is anchored in the health literacy model by Nutbeam (2000) and as a result from a systematic review presents a rather practical definition by stating that FL describes "competencies needed to maintain a healthy diet" (Krause et al., 2018, p. 278). In contrast to this definition by Krause et al. (2018), Vidgen and Gallegos (2014, p. 54), claim within a more holistic definition, that FL "empowers individuals, households, communities or nations to protect diet quality through change and strengthen dietary resilience over time. It is composed of a collection of inter-related knowledge, skills and behaviours required to plan, manage, select, prepare and eat food to meet needs and determine intake". However, the above mentioned more practical definition appears to be better suited for the aim of this dissertation, because the investigated relations and changes of FL are predominantly examined on the personal level with less consideration given to environmental aspects and without DB as an integrated factor of the FL model.

The model by Gréa Krause et al. (2018) distinguishes between three different levels: functional, interactive and critical FL. Functional FL involves knowledge and skills to acquire and comprehend information related to food. For example the functional level of FL, could represent the acquisition and understanding of information on healthy diets from a leaflet or an expert video presentation, thus representing an unidirectional mean of communication (Krause et al., 2016; Nutbeam, 2000). Interactive FL entails the capability to communicate this information in relation to food and healthy diet during interactions between people, which can be described by the practical example to independently execute and effectively communicate food-related knowledge to influence DB of social groups (Gréa Krause et al., 2018). Critical FL is focussed on thoughtfully analysing information concerning food and healthy diet obtained from unidirectional or interactive communication to maintain and achieve control over these situations in the food environment (Krause et al., 2016). This

level of FL can be seen as the individual's resilience to act on social adversity or other determinants, which might influence healthy DB (Nutbeam, 2000). This model is presented in Figure 4.

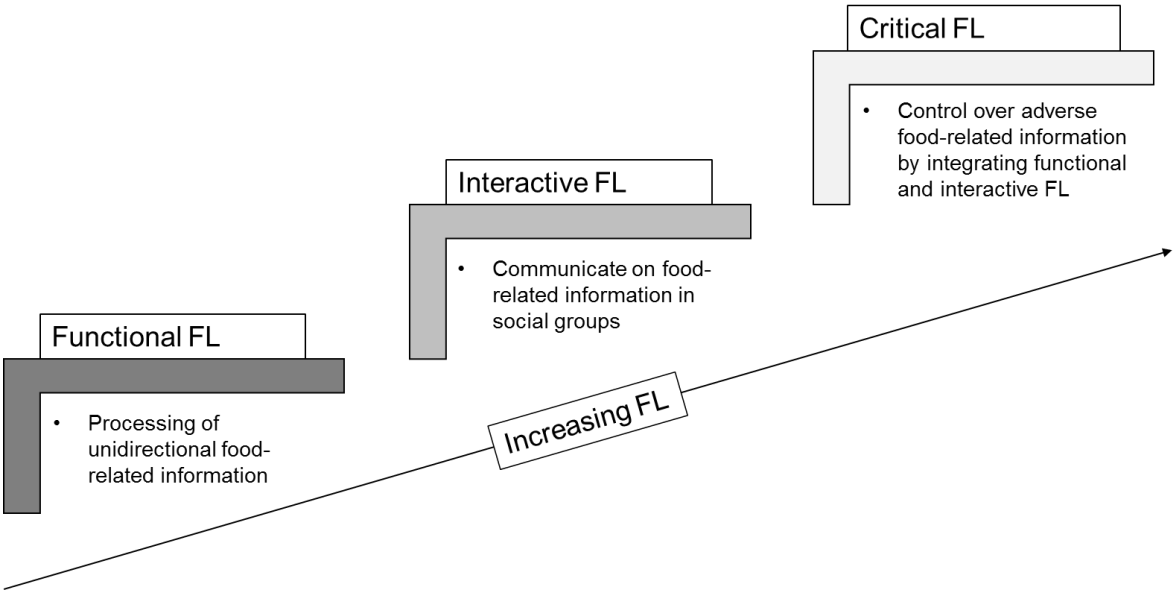

Figure 4. Levels of FL Adapted from Krause et al. (2018) and Nutbeam (2000)

In line with research on health literacy and PAHCO, FL is theoretically assumed to be a key individual trait for individuals to foster healthy DB and sustainable diet quality and thereby affecting risk factors for NCDs (Ares et al., 2024; Palumbo, 2016). Furthermore, this assumption for FL is linked to the characteristics of personality traits, which suggest changeability for example by interventions and relative temporal stability over time (Roberts et al., 2017; Wiek et al., 2011). Also due to this trait-like characteristic of FL, interventions targeting FL have tried to address this construct to promote FL and thereby also tried to achieve lasting improvements in healthy DB and to increase individuals' HrQoL (Palumbo, 2016), for example in the workplace (Daker et al., 2024).

2.5.2 Current Research on FL, DB and Health in WHPPs

The state of research in general supports the theoretical assumptions of FL's connection with DB and health in working aged adults (Amouzandeh et al., 2019; Begley et al., 2019; Daker et al., 2024; Faramarzi et al., 2019; Luta et al., 2018; West et al., 2020). Concerning the connection between FL and DB, the review by Amouzandeh et al. (2019) on FL measures examines that these two constructs are positively associated. This connection is for example underlined by positive small-to-moderate effect sizes as examined in a cross-sectional South Korean population study (Lee et al., 2023), a cross-sectional Dutch study (Poelman et al., 2018), and a nationwide cross-sectional study with Japanese adults (Murakami et al., 2023). These studies try to fill a gap in current research,

which is outlined by the authors of the review mentioning methodical shortcomings regarding the employed DB measures and a great heterogeneity in FL measures (Amouzandeh et al., 2019). However, the aforementioned studies target mixed working aged adult populations without focusing on specific occupations, which leaves the potential connection between FL and DB in OWs partially in question.

Besides the connection between FL and DB, Truman et al. (2017) state in their scoping review that only a few studies address the connection between FL and health outcomes. This gap has been addressed by a Turkish cross-sectional study reporting small-to-moderate positive effect sizes for the connection of FL and HrQoL in a general adult population (Baş et al., 2024). This result is in line with findings from a seven-week FL intervention, which had a small positive effect on HrQoL also six months after the programme (Rees et al., 2022). While low HrQoL is an essential risk factor in the prediction of NCDs, other risk factors, such as indicators of NAFLD show mixed findings concerning the connection to FL (Carroll & Rotman, 2023; Figueroa et al., 2024; Haigh et al., 2019). The cross-sectional nationwide study by Carroll and Rotman (2023) reported a connection between NALFD and DB, but no significant connection between FL and NAFLD, which might be due to the regression method employed in their analysis. In contrast to these results, Haigh et al. (2019) found that certain aspects of FL, such as diet-related knowledge and skills, could promote changes in DB and in return improve NAFLD in an intervention on healthy DB. These contradictory findings require further research on FL, DB and risk factors for NCDs to assess and possibly quantify the potential of FL.

Whereas the majority of research on FL is cross-sectional, Begley et al. (2019) reported encouraging findings from an intervention targeting FL at the end of the intervention and after a follow-up period of six months. This intervention consisted of a four-week nutrition education and cooking programme aimed at low to middle-income Australians and displayed improvements in FL and DB. Furthermore, a four-week online FL programme for Australian adults led to enhanced FL and increased consumption of fruits and vegetables (Ng et al., 2022). Although both studies show an increase in FL and a positive effect on DB, these studies are lacking long-term follow-up measurements, which could yield insight into the temporal stability of FL, as a trait-like construct, and into the long-term effect on DB. Moreover, these studies do not specifically address OWs, which also due the aforementioned conditions of work and their proximal outcomes might struggle to display healthy DB (Clohessy et al., 2019). Glympi et al. (2020) underline this limitation of current FL interventions in their systematic review on dietary interventions at the workplace for OWs, which includes interventions addressing aspects of FL, such as food skills and knowledge. They postulate that most interventions included in their review display limited or no follow-up periods.

2.5.3 Demands for Future Research on FL in OWs' Health Promotion

The current state of research on FL, DB and health in OWs points towards several demands for future studies, which is additionally underscored by the prevalence of risk factors for NCDs in this target group (Gupta et al., 2022; Strauss et al., 2022) and the potential barriers for DB arising from the conditions of office work (Clohessy et al., 2019). In view of the contrasting results on the connection of FL with NAFLD in previous research (Carroll & Rotman, 2023; Haigh et al., 2019) future studies one the one hand should, try to gain further knowledge by employing different statistical methods, such as path analyses (Alwin & Hauser, 1975), to test the complex relationships between FL, DB and NAFLD. On the other hand, focusing on the target group of OWs specifically could account for the influencing factor of occupation on the individual's risk for NAFLD, which might affect the connection between FL and objective health outcomes (Strauss et al., 2022). Such a focus on OWs and different statistical methods could endorse previous findings and test the validity of FL as a determinant of DB and health in light of the methodological challenges surrounding the self-report assessment of DB (Subar et al., 2015). Lastly, supplementing previous findings on FL in the context of DB and NAFLD would illustrate the potential of FL for the development of WHPPs as a mean to mitigate the risk of NCDs in OWs.

Furthermore, the potential of FL for the development of WHPPs in the target group of OWs should be examined in longitudinal research, which to the knowledge of the author has not been investigated by previous studies. However, further investigation is in particular needed because longitudinal studies promoting healthy DB in OWs (Glympi et al., 2020) or FL in adult samples (Begley et al., 2019) are scarce and lack follow-up periods beyond six months. This notion is highlighted by a systematic review on randomised control trials addressing DB in the general adult population, which reports that most participants were able to maintain DB changes 12 months after the intervention, but showed diminishing effects in each of the following years (Chapman, 2010). Testing the assumption of FL as a trait-like construct beyond the period of 12 months, which is lacking in current research to the knowledge of the author, could deliver insight also into lasting-changes on DB and health deriving from FL. Because of this result, science and practice could translate existing programmes or develop new WHPPs targeting FL in OWs helping this population to bypass barriers for healthy DB at the workplace and thereby have a health-enhancing impact in the prevention of NCDs.

2.6 Research Goals of the Dissertation Project

Due to the aforementioned possible benefits associated with domain-specific health literacy, namely PAHCO and FL, and the need for health promotion in OWs as well as the lack of research on these health literacy facets in this target group, this dissertation project pursues two main research goals with two sub-objectives each.

The first research goal aims at gaining further insight on the lack of research (Schmid et al., 2020) and the partially inconsistent findings of previous studies (Carroll & Rotman, 2023; Haigh et al., 2019) addressing the connections of domain-specific health literacy, health behaviour and objective health outcomes. Targeting this research goal could strengthen the potential of domain-specific health literacy to promote health behaviour and cardiovascular health in WHPPs resulting in the prevention of NCDs in OWs. This research goal will be pursued within two sub-objectives addressing PAHCO, LTPA and MetS as well as FL, DB and NAFLD, respectively, by two separate studies within the same population of OWs. Hence, the first sub-objective (1) results in the first study, which investigates the relationships of PAHCO with LTPA and MetS. Accordingly, the second sub-objective (2) brings about the second study of this dissertation project, which examines the relationship of FL with DB as well as NAFLD.

The second research goal extends previous longitudinal studies on domain-specific health literacy (Begley et al., 2019; Ng et al., 2022; Rosenstiel et al., 2021; Volk et al., 2021) in various populations and WHPPs concerning PA and DB (Chapman, 2010; Glympi et al., 2020) in the specific target group of OWs. The pertinent studies examine PAHCO and FL in OWs over the course of a comprehensive WHPP with follow-up measurements after six and 18 months to explore the constructs changeability and temporal stability. Furthermore, the goal is to examine the influence of these constructs on the health behaviours of LTPA and DB, respectively. This longitudinal design could help to substantiate the assumption of changeability and temporal stability in these domain-specific health literacy constructs, which implies that lasting health behaviour and health benefits might derive for example from WHPPs targeting theses constructs in OWs. This research goal is addressed by the third and the fourth sub-objective, which examine PAHCO and FL in two separate studies, within the same population as well as WHPP. The third sub-objective (3) culminates in study three, which examines the effect of multi-component WHPP on PAHCO, LTPA and HrQoL in an in-person multi-component WHPP focusing amongst others on PAHCO and HEPA with follow-up measurements after six and 18 months. Accordingly, the fourth sub-objective (4) investigates the changes of this in-person multi-component WHPP, which also focused on aspects of FL and DB, on FL and DB at the same measurement point as mentioned in study three, which results in the fourth study of this dissertation project.

3 Methods

These research goals are investigated within a project, which had the aim to comprehensively evaluate occupational health checks and the ensuing in-person WHPPs as a part of the occupational health management system of a large German company from January 2019 to June 2022 (Pelster et al., 2022). The company designed the in-person multi-component WHPP, which was central for the third and the fourth sub-objective of this dissertation project, to enhance PA and healthy DB in order to promote employees' cardio-vascular health and HrQoL. This WHPP spanned three weeks and was conducted by three exercise therapists, a nutritionist, a physician, and a psychologist, accommodating up to 60 participants per trial. Furthermore, this WHPP took place at a wellness hotel in Hof, Bavaria, Germany. Employees were informed about the evaluation project's objectives and scope by oral presentations, via email, or through brochures. Participants completed surveys on paper at the start and at the end of the WHPP, and online for follow-up assessments six and 18 months later, respectively, using individual pseudonyms for identification. Informed consent was obtained at the beginning of the WHPP and also for the online surveys during the follow-ups, adhering to the company's privacy policies. Ethical approval for the evaluation project and the studies of this dissertation project was granted by the Ethics Committee of the Technical University of Munich (IRB number: 645/20 S-KH), and the interventional studies were registered in the German Clinical Trials Register (DRKS00030514).

With respect to the participating sample, the company had an overall proportion of about 80 % of the employees working in an office environment. Yet, with the exception of the second study, where the type of occupation served as a control variable, the type of work served as inclusion or exclusion criteria. Furthermore, employees were eligible, if they met the inclusion criterion of being free from acute illness or disease prohibiting the participation in WHPP. Out of the 446 eligible employees during the data collection period, 388 (87 %) provided written informed consent to take part in the evaluation project. Among them, 327 (73 %) employees fulfilled the inclusion criteria of working in an office setting and not having any acute illness or condition that would prevent participation in WHPPs. Mean age of the final sample was 50.9 (*SD* = 6.4) years. The participants were predominately male (75 %), with about two thirds having a higher educational background (64 %) and the majority reporting to have a partner (81 %).

To examine the research goals of this dissertation project the health behaviour of PA was assessed at the workplace employing the work subscale of the Baecke Physical Activity Questionnaire (Baecke et al., 1982) and during leisure-time with the Godin–Shepard Leisure-Time Physical Activity Questionnaire (Godin & Shephard, 1985). DB was analysed

using a Food Frequency Questionnaire (FFQ; Winkler & Döring, 1998). Furthermore, The Alcohol Use Disorders Identification Test Consumption (AUDIT-C) was employed to examine the alcohol consumption (Bradley et al., 2007). To measure PAHCO the evaluation project employed the questionnaire on the PAHCO model developed by Sudeck and Pfeifer (Sudeck & Pfeifer, 2016) and FL was examined with the questionnaire of FL by Krause et al. (2016). HrQoL was examined using the SF-12 version 2.0 (Wirtz et al., 2018). Furthermore, participants answered questions on age, gender, educational background and relationship status. In addition to these self-report measures, the MetS associated risk was assessed by calculating the Metabolic Syndrome Severity Score (MetSSS) (Gurka et al., 2014) during occupational health checks at the start of the WHPP, using parameters aligned with the MetS classification of the National Cholesterol Education Program Adult Treatment Panel-III (NCEP ATP III) (DeBoer & Gurka, 2017). These parameters include blood pressure, waist circumference, triglycerides, HDL cholesterol, and fasting glucose levels. NAFLD was examined with the Fatty-Liver Index (FLI) (Lind et al., 2020), which contains the biomarkers of body mass index, waist circumference, triglycerides and γ-glutamyltransferase as a valid and economic indicator for this cardio vascular risk factor of NCDs (Koehler et al., 2013; Meffert et al., 2014). The following chapters will describe the specific methods used in the individual studies in detail.

3.1 Study 1

The first study with the sub-objective of investigating the connections of PAHCO, LTPA and MetSSS, had a sample of 316 participants (25 % female, *M* = 50.9, *SD* = 6.4 years) after removal of univariate and multivariate outliers meeting the inclusion criteria. The self-report data was collected via paper-pencil questionnaires and comprised amongst others sociodemographic variables, LTPA, PAHCO and HrQoL. The objective parameters to assess MetSSS were examined by the company's physician during an occupational health check at the start of the in-person multi-component WHPP. The data analyses for the first study concern the aforementioned self-report and objective data.

Prior to the data analyses missing values were examined and imputed by applying multivariate-chained equations (Azur et al., 2011) following the recommendations by Graham (2009). Subsequently, the assumptions for regression analyses of linearity, normality, homoscedasticity, and independence of the residuals were tested prior to the following analyses (Ernst & Albers, 2017). The ensuing data analysis of this study is in accordance with a study by Carl, Grüne, et al. (2020). The analyses plan consists of a descriptive bivariate correlation matrix of all continuous variables (Armstrong, 2019; Pearson, 1932), multivariate linear regressions for PAHCO, LTPA and MetSSS as separate outcomes and for all sociodemographic variables as predictors (Berndt & Savin, 1977) and SEM (Bielby & Hauser, 1977; Cheung et al., 2023). SEM was employed to pursue the first

research goal (first sub-objective) of this study, but was based on the theoretical background and the results of the previous analyses of this study. SEM analysis in comparison to multivariate linear regression analyses has the advantages of measuring latent variables and empirical testing of a theoretical model by accounting for multiple moderating or mediating predictor or outcome variables concurrently (Thakkar, 2020). The underlying theoretical model of this study was the integrative health literacy model by (Sørensen et al., 2012), which assumes a connection between health literacy, health behaviour and health outcomes. In addition, the PAHCO model (Sudeck & Pfeifer, 2016) accordingly supposes a connection between this domain-specific health literacy facet, health-enhancing PA and health, which was previously tested by Carl, Grüne, et al. (2020). However, in that previous study only subjective health outcomes were used and a different occupational group was targeted (Carl, Grüne, et al., 2020), which in comparison to the first study in the present dissertation project has the potential limitations of report bias or restricted transferability of the results to OWs.

Data preparation and statistical analyses were performed using R and RStudio software (Version 3.4.3; RStudio Inc., Boston, MA, USA) (Team, 2016). Multivariate linear regressions standardised estimates (β) as well as 95 % confidence intervals (CIs) were calculated. The significance level was adjusted to $p < 0.0125$ with Bonferroni correction applied to account for potential multiple testing issues (VanderWeele & Mathur, 2019). We evaluated the SEM's global fit using chi-square/df (χ^2/df: acceptable ≤4, good ≤2), CFI (acceptable ≥0.95, good ≥0.97), RMSEA (acceptable ≤0.08, good ≤0.05), and SRMR (acceptable ≤0.10, good ≤0.05). Standardised loadings (λ) were used to validate the PAHCO model and to test the study's hypotheses, with a significance level set at $p < 0.05$ (Hu & Bentler, 1999).

3.2 Study 2

After removing univariate and multivariate outliers, a total of 372 participants (38 % female, M = 50.8, SD = 6.3 years), out of which 310 were OWs, served to examine the connections of FL, DB and NAFLD (first research goal/second sub-objective). The self-report data of the second study was collected within the paper-pencil questionnaires of the first study and contained amongst others sociodemographic variables, DB, FL and HrQoL. In line with the first study, the objective parameters to examine NAFLD were collected in an occupational health check at the baseline of the in-person multi-component WHPP by the company's physician. The second study's data analyses comprise this self-report and objective data.

The data preparation and analyses plan of the second study was partially in line with the first study to allow for tentative comparisons between the results of the studies (Valentine et al., 2011). The second study also addressed the empirical examination of the

health literacy model by Sørensen et al. (2012) exploring the connections of the domain-specific health literacy aspect of FL, with the health behaviour of DB and NAFLD as a cardiovascular risk factor. While data preparation, correlation analyses and linear multivariate regression analyses were methodologically equal to the first study, the second study employed path analysis instead of SEM (Werts & Linn, 1970). Both analyses are used to empirically specify theoretical models and examine direct and indirect connections, but path analyses does not allow the inclusion of latent variables, which may be criticised as error terms are not estimated within the measurement model (Devlieger & Rosseel, 2017). However, a recent study showed in a meta-comparison that there is artificial bias in parameter estimates for models involving latent variables, whereas path analyses with composite scores are more powerful and more accurate to determine effect sizes (Deng & Yuan, 2023). In comparison to previous research, which primarily used linear multivariate regression analyses, neither SEM nor path analyses were previously applied to test the theoretical model on FL by Krause et al. (2016) in connection with DB and NAFLD examining the direct and indirect connections of these variables.

R and RStudio software (Version 3.4.3; RStudio Inc., Boston, MA, USA) was used to conduct data preparation and statistical analyses (Team, 2016). Amongst other coefficients, the multivariate linear regressions delivered standardised estimates (β) as well as 95 % confidence intervals (95 % CIs) to inform the path analyses. The path analyses global fit was estimated using chi-square/df (χ^2/df: acceptable ≤4, good ≤2), CFI (acceptable ≥0.95, good ≥0.97), RMSEA (acceptable ≤0.08, good ≤0.05), and SRMR (acceptable ≤0.10, good ≤0.05) (Hu & Bentler, 1999). For the interpretation of the variables in the path analyses, 95 % CIs, standard errors (SE), and standardised estimates (β) were examined. Furthermore, the adjusted total explained variance by the predictors was examined using R^2 (James et al., 2013).

3.3 Study 3

The third study addressed the changeability and temporal stability of intervention-induced changes in PAHCO with a total of 328 participants (34 % female, *M* = 50.9, *SD* = 6.4 years), out of which 149 remained in the final analysis. This study examined the second research goal (third sub-objective) of changeability and subsequent temporal stability of intervention-induced PAHCO changes and its influence on LTPA and HrQoL. Paper-pencil questionnaires were used for the first and the second measurement before and at the end of the three-week in-person multi-component WHPP. Online questionnaires were employed for the ensuing follow-up data collection after six and 18 months. The measurements at each time point contained questionnaires on sociodemographic variables, LTPA, PAHCO and HrQoL. A longitudinal collection of MetSSS was not possible due to contact restrictions

during the COVID-19 pandemic, which impaired the consultation of the company's physicians for WHPPs.

Concerning health-enhancing PA, the programme started with an initial assessment of the participants' health status by an independent physician. The physician's examination and consultation also served to advise participants on PA intensity and exercise session content for the following WHPP. By informing participants about possible health consequences and setting personalised health-enhancing PA goals. The participants received a printed summary report of their physical examination results (e.g., blood pressure, triglycerides) and goals for PA promotion over the course of the WHPP. In a next step, exercise therapists introduced participants to the exercise facilities in three 90-minute sessions and conducted a 90-minute workshop on the link between PA and health. These initial sessions provided instructions and demonstrations on exercise behaviours and basic knowledge on health-enhancing PA. For the next 15 days, participants followed a structured routine, which contained a 45-minute run/walk in the morning and a 90-minute exercise session after breakfast, both guided by exercise therapists. In addition, the psychologist led a 90-minute practical session on relaxation techniques or health-enhancing PA workshops, respectively, after lunch. The evenings were free for leisure-time activities or attending presentations on mental health and PA. The programme emphasised behavioural practice, feedback, self-monitoring, and social support, integrating psychological, medical, and exercise science perspectives. In the final week, a second physical examination was conducted to monitor changes and set goals for maintaining health-enhancing PA after completing the WHPP. As an additional tool to reach these goals, instructions for goal setting, action planning, and problem-solving strategies were provided. Furthermore, workshops on the last two days focused on refining health-enhancing PA implementation intentions and transitioning these changes into daily life. Further details on the curriculum, materials, and schedule can be found in the supplementary files of the study's manuscript as well as in Pelster et al. (2022).

The research goal was pursued within a per protocol analysis, because the primary focus of the present study is placed on the theoretical assumptions of PAHCO rather than the intervention's effectiveness (Armijo-Olivo et al., 2009). Missing data, such as from partially incomplete survey responses, were imputed using multivariate chained equations, if the assumption of data missing at random was fulfilled (Azur et al., 2011). Current recommendations for handling outliers and the assumptions of linearity, normality of variances, homoscedasticity and independence of the residuals were applied prior to hypothesis testing (Ernst & Albers, 2017). Linear mixed model regressions were employed to analyse the changeability and temporal stability of PAHCO, the three subscales of the used measure and the secondary outcomes of LTPA and HrQoL over the four measurement

times. This mixed model regression approach holds the advantage of accounting for individual or cluster-specific effects in the analysis of hierarchical data and can increase statistical power in comparison to fixed linear regression models (Yang et al., 2014). Exploratory analyses of the hierarchical data structure showed the best fit for a random intercept only model, which introduced a random effect for each participant and accounted for inter-individual differences over the four measurement times (pre- and pot-intervention, six and 18 months follow-up). HrQoL, LTPA, age, gender, relationship status and educational level served as fixed effects in the linear mixed model regressions investigating the changeability and subsequent temporal stability of PAHCO and the subscales. In addition to these regressions, Tukey's post hoc test (Kim, 2015) was employed to assess the temporal stability of PAHCO and its subscales at the first and second follow-up measurements compared to the levels after completing the in-person multicomponent WHPP (Liu et al., 2010).

The linear mixed regression models were compared amongst others to the null model using Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), and adjusted R-squared (R^2). Standardised estimates (β), confidence intervals (*95 % CI*), and *p*-values were analysed to assess the influence of the fixed effects on the outcome. Standardised estimates from the linear mixed model regression analyses and post hoc tests were interpreted as indicating small (≈0.10), moderate (≈0.30), or strong effects (≈0.50) (Cohen, 1977). To account for multiple testing, we determined the significance level for the linear mixed model regression analyses and post hoc tests to $p < 0.01$ (VanderWeele & Mathur, 2019). Data management for the third study was conducted by R and RStudio software (Version 3.4.3; RStudio Inc., Boston, MA, USA) (Team, 2016).

3.4 Study 4

The fourth study addressed the changeability and temporal stability of FL and its influence on DB (second research goal/fourth sub-objective) with a sample of 303 participants (30 % female, $M = 50.0$, $SD = 6.3$ years), who in parts were also included in the third study. The initial and final measurements before and after the three-week in-person multi-component WHPP were administered with paper-pencil questionnaires. Subsequent follow-up data collection at six and 18 months utilised online questionnaires. Each measurement included inquiries about sociodemographic variables, FL and DB. Due to the COVID-19 pandemic, the longitudinal collection of NAFLD was not feasible, as consultations with the company's physicians for WHPPs were strongly restricted during this phase of the pandemic.

With respect to promoting healthy DB, the WHPP started with a health check by an independent physician to assess participants' health status and collaboratively set individual goals for DB and daily calorie intake with physical education teachers and a dietitian. In

addition, participants received information on nutrient content of foods and effects, alongside visuals illustrating ideal portion sizes and calorie amounts during breakfast, lunch and dinner over the course of the three-week WHPP. The dietitian offered additional insights into meal preparation and cooking skills during meal times. The programme also featured presentations by psychologists on health risks and DB change strategies. In the first week, a 4-hour workshop on DB covered topics such as macronutrients, their physiological roles, health implications, and recommended consumption levels according to the guidelines published by the German Nutrition Society (Deutsche Gesellschaft für Ernährung e.V., Bonn, Germany). Individual coaching sessions with the dietitian, physical education teachers, and psychologists aimed to reinforce personal motivation and develop skills for sustaining healthy DB post-programme. During the final week, another medical health check assessed objective changes in participants' health parameters and refined individual goals for the participants' DB after the WHPP. Participants received instruction on problem-solving strategies from the physician, the physical education teachers, and the dietitian to strengthen long-term motivation and behavioural skills. Essential information, including presentation slides, nutrient tables, and recipes, was provided to participants for use at home after completion of the WHPP. Additional details on the WHPP with regard to DB are included in the supplements of this manuscript and partially in the evaluation protocol by Pelster et al. (2022).

Per protocol analysis served to examine the research goals of FL's changeability and temporal stability as well as its effect on DB (Armijo-Olivo et al., 2009). However, this study also comprised intention-to-treat analyses to assess whether dropouts of the study affected the findings of the per protocol analyses, which would reduce the bias due to study attrition (Ranganathan et al., 2016). Similar to the third study, multivariate chained equations were used to impute missing values (Azur et al., 2011). Outlier handling and the assumption testing before the regression analyses were conducted based on common recommendations (Ernst & Albers, 2017; Tabachnick & Fidell, 2007). The changeability due to the WHPP and subsequent temporal stability of FL was examined in a linear mixed model regression. Another mixed model regression investigated the effect of FL on DB over the measurement period. Random intercept only models for each participant showed the best model fit. While FL was the outcome variable of the first model and DB the outcome of the second model, measurement time, age and gender were included as fixed parameters in both models. In addition, FL was a fixed effect predictor in the second model.

Model fit was assessed following the recommendations by Nakagawa and Schielzeth (2013), reporting both the marginal R^2, which represents the proportion of variance explained by the fixed factors, and the conditional R^2, which represents the proportion of variance explained by the entire model, including both fixed and random effects. In line with

the third study, standardised estimates (β), confidence intervals (*95 % CI*), and *p*-values were calculated to examine the fixed effects on the outcome variable. Effect sizes are categorised as weak (β ≈ 0.10), moderate (β ≈ 0.30), or strong (β ≈ 0.50) (Cohen, 1977). Data preparation and analysis was conducted with the statistical analysis software programmes R and RStudio (Version 4.2.0) (Team, 2016).

4 Publications

4.1 Article 1

Authors:

Simon Blaschke, Johannes Carl, Jan Ellinger, Ulrich Birner, Filip Mess

Title:

The Role of Physical Activity-Related Health Competence and Leisure-Time Physical Activity for Physical Health and Metabolic Syndrome: A Structural Equation Modeling Approach for German Office Workers

Journal:

International Journal of Environmental Research and Public Health

DOI:

10.3390/ijerph181910153

Submission:

The manuscript was submitted in August 2021, and accepted and published in September 2021 in the section *Occupational Health and Safety* of the *International Journal of Environmental Research and Public Health*. The *International Journal of Environmental Research and Public Health* is an international peer-reviewed open-access journal publishing research in the interdisciplinary area of occupational health sciences, public health and health promotion. Review reports can be accessed online.

Summary:

Insufficient PA is a relevant risk factor in OWs. Low levels of PA in this occupational group can lead to MetS and deteriorated physical health. PAHCO has the potential to promote the amount and quality of PA to enhance a physically active and healthy lifestyle. While previous studies have examined the connection of PAHCO with PA and subjective health measures in different occupational groups, objective health outcomes, such as MetS, and the relevant occupational group of OWs have been neglected so far. Therefore, this study explores the relationships between PAHCO, LTPA, physical health, and MetS among OWs in Germany. In a cross-sectional study, 316 OWs (25 % female) completed self-report questionnaires and underwent an occupational health check to assess their MetSSS. SEM revealed a strong positive association between PAHCO and LTPA, and a small positive association with physical health. PAHCO also showed a significant negative association with MetSSS. While LTPA positively mediated the relationship between PAHCO and physical health, it was not a significant mediator between PAHCO and MetSSS. These results confirm the importance of PAHCO in connection with LTPA and subjective physical health outcomes as established in previous research for different adult working populations.

More importantly, this study extends previous research on PAHCO by incorporating the objective health outcome of MetS. To the knowledge of the author, currently no other study on PAHCO has included objective health outcomes in the health promotion context, which makes this study a crucial contribution to the field. Additionally, this study explores that the subscales of PASR and CCPT, which comprise a motivational-volitional component of maintaining PA and a focus on qualitative aspect to promote health-enhancing PA, might present particular benefits for mitigating the risk of MetS and impaired physical health in this population. These findings underscore the relevance of PAHCO for the development of WHPPs in this target group. Furthermore, the PAHCO model with the different sub-competencies could also be beneficial to develop tailored and individualised programmes depending on an individual's needs to access the health-enhancing potential of PA in the population of OWs.

Contribution:

Simon Blaschke was the leading author of the article. Ulrich Birner and Filip Mess were responsible for acquisition and funding. Simon Blaschke had the lead in the idea development for the study. Simon Blaschke and Ulrich Birner coordinated the data collection process. Simon Blaschke had the main responsibility for the study design with Johannes Carl and Filip Mess assisting in the refinement. Simon Blaschke and Johannes Carl executed the data analysis. Simon Blaschke wrote the article in its published form with Johannes Carl contributing fruitful ideas in the writing process. All co-authors revised the manuscript in the submission and publication process.

4.2 Article 2

Authors:

Simon Blaschke (shared first authorship), Nele Schad (shared first authorship), Melina Schnitzius, Klaus Pelster, Filip Mess

Title:

The Connection between Non-Alcoholic Fatty-Liver Disease, Dietary Behaviour, and Food Literacy in German Working Adults

Journal:

nutrients

DOI:

10.3390/nu15030648

Submission:

The manuscript was submitted in December 2022, and accepted and published in the special issue *"Relationship between Diet and NAFLD: From Pathogenesis, Clinical and Epidemiological Studies to Prevention and Health Policy"* of the journal *Nutrients* in January 2023. *Nutrients* is an international, peer-reviewed open access journal to publish studies related to Human Nutrition, which integrates the interdisciplinary areas of public health, metabolic syndrome as well as the section *"Nutritional Policies and Education for Health Promotion"*. Review reports can be accessed online.

Summary:

Working adults in Germany are prone to develop NAFLD. This condition is associated with increased cardiovascular and overall morbidity and mortality affecting approximately 18 million adults in Germany, which underlines the importance of addressing factors associated with this disease. The conceptual model of NAFLD proposes amongst other factors DB and health knowledge as critical factors in the development of NAFLD, because both factors can be directly positively and negatively connected to this disease. These factors share large conceptual common ground with the concept of FL, which encompasses the skills and knowledge needed to promote healthy DB and prevent diseases such as NAFLD. Empirically, to the knowledge of the author, the potential of FL in preventing NAFLD remains unclear, as this connection has not been tested directly and may be indirectly mediated by DB. Thus, this study aimed at investigating the direct and indirect relationships between FL, DB, and NAFLD using a mediation model in a path analytic approach. To address this aim, a cross-sectional study was conducted with 372 working adults, of whom 38 % were female, at the start of a three-week multicomponent in-person WHPP. Participants completed self-report questionnaires assessing their FL and DB before the WHPP commenced. Additionally, a physician from the company evaluated the participants' indicators for NAFLD, namely the FLI, during an occupational health check-up. In the

mediation model, FL demonstrated a moderate significant direct relationship with DB, but no direct relationship with the FLI. However, DB showed a small to moderate relationship with this indicator for NAFLD, suggesting that the connection between FL and NAFLD might be indirectly mediated through DB alone. This study addressed a crucial gap in the literature by offering a preliminary understanding of the intricate relationships between FL, DB, and indicators of NAFLD in German working adults. In detail, these findings underscore the importance of DB in preventing NAFLD. Moreover, FL appears to play a crucial role in enhancing healthy DB, potentially serving as a key resource for NAFLD prevention. These findings could assist researchers in the design of future cross-sectional studies that incorporate multiple factors of the conceptual model of NAFLD, as well as longitudinal studies that explore the proficiency of FL and its impact on DB for NAFLD prevention in working adults. Additionally, our results may encourage practitioners to pilot WHPPs aimed at improving DB and consequently preventing NAFLD by integrating environmental and personal intervention components that address aspects of FL.

Contribution:

Simon Blaschke and Nele Schad were the leading authors of this article. Klaus Pelster and Filip Mess had the responsibility of acquiring the funding. Simon Blaschke developed the idea of this study. Simon Blaschke and Klaus Pelster conducted the coordination of data collection. Simon Blaschke had the main responsibility for the study design with Filip Mess assisting in the refinement. Simon Blaschke and Nele Schad executed the data analysis. Simon Blaschke and Nele Schad wrote the first draft of the article while Melina Schnitzius contributed to the writing process by giving valuable feedback. All co-authors revised the manuscript in the submission and publication process.

4.3 Article 3

Authors:

Simon Blaschke, Johannes Carl, Klaus Pelster, Filip Mess

Title:

Promoting physical activity-related health competence to increase leisure-time physical activity and health-related quality of life in German private sector office workers

Journal:

BMC Public Health

DOI:

10.1186/s12889-023-15391-7

Submission:

The submission of this manuscript was made in November 2022 and the final version published in the journal *BMC Public Health* in March 2023. *BMC Public Health* is an international, peer-reviewed open access journal publishing studies in connection with the epidemiology of diseases and the understanding of all aspects of public health, which places the focus for example on the behavioural and occupational correlates of health and disease, and the impact of interventions. Review reports can be accessed online.

Summary:

Also due to a physically predominantly inactive occupational context, OWs are susceptible to reduced HrQoL and low levels of health-enhancing PA. The PAHCO model and interventions related to this model assume to support long-term improvements in HrQoL and health-enhancing PA. While cross-sectional studies show a stable connection between PAHCO, PA and health outcomes, these assumptions on long-term connections, however, have not been empirically validated and are dependent on the temporal stability and changeability of PAHCO. Therefore, the purpose of this study is to investigate the changeability and temporal stability of PAHCO in OWs within an interventional design as well as to examine the long-term impact of PAHCO on HrQoL and LTPA. A three-week in-person WHPP with an emphasis on PAHCO and health-enhancing PA was completed by 328 OWs (34 % female, *M* = 50.9, *SD* = 6.4 years). Using linear mixed model regressions, the primary outcome of PAHCO and the secondary outcomes of HrQoL and LTPA were assessed at four measurement intervals across an 18-month period in a pre-post design. Between the baseline and the measurement time point at the end of the WHPP, PAHCO showed a significant strong positive increase. Additionally, there was no decline in PAHCO examined when comparing the PAHCO level at the end of the WHPP to those six months and 18 months after the WHPP, respectively. Furthermore, there was a small to moderate positive effect of the PAHCO subscale of PASR on LTPA and HrQoL. Additionally, HrQoL was positively influenced by the subscale of CCPT with a small to moderate effect. The

findings support both the changeability due to a WHPP and the temporal stability of PAHCO afterwards, as well as the effects on on LTPA and HrQoL that have been theoretically hypothesised. These results demonstrate PAHCO's potential for developing WHPPs leading to long-term enhancements in OWs' HrQoL and health-enhancing PA. However, in particular due to limitations regarding the pre-post study design, additional research is required to further validate our findings because the present study is only the first one in a non-clinical sample of adults investigating the changes in PAHCO after an intervention.

Contribution:

Simon Blaschke had the lead in the article development. Klaus Pelster and Filip Mess were responsible for acquisition and funding. Simon Blaschke had the lead in the idea development of the idea for the research question and the ensuing development process of this study. Simon Blaschke had the main responsibility for the study design. Simon Blaschke coordinated the data collection process. Simon Blaschke had the lead in the data analysis and was assisted by Johannes Carl in the data analysis plan. Simon Blaschke wrote the article with Johannes Carl and Filip Mess assisting in the writing process. All co-authors revised the manuscript during the submission and publication process.

4.4 Article 4

Authors:

Svenja Meyn (shared first authorship), Simon Blaschke (shared first authorship), Filip Mess

Title:

Food Literacy and Dietary Intake in German Office Workers: A Longitudinal Intervention Study

Journal:

International Journal of Environmental Research and Public Health

DOI:

10.3390/ijerph192416534

Submission:

The manuscript was submitted in November 2022, and accepted and published in December 2022 in the section *Occupational Health and Safety* of the *International Journal of Environmental Research and Public Health*. The *International Journal of Environmental Research and Public Health* is an international peer-reviewed open-access journal publishing research in the interdisciplinary area of occupational health sciences, public health and health promotion. Review reports can be accessed online.

Summary:

One of the main reasons why NCDs are becoming more and more prevalent worldwide and in Germany is among other factors the widespread adoption of unhealthy DB. At the workplace and in particular in OWs unhealthy DB is also a crucial topic related to their working conditions, such as high work investment and long working hours, impairing DB. FL can help to navigate these work-related barriers and promote healthy DB, which in return mitigates the burden of NCDs also in the population of OWs. Early findings from research have shown how FL can empower people to make better nutritional choices, but the majority of research on FL as of yet has investigated this construct cross-sectional study designs. Furthermore, studies on FL interventions in the target group of OWs are particularly rare, which in view of the research need underlines the relevance of longitudinal research on this topic. This study had the aim to evaluate the changes in FL and DB following a three-week in-person multicomponent WHPP that gave participants in-depth knowledge and skills about nutrition and health. In a sample of 144 German office workers (30.0 % female), we sought to determine the short- and long-term effects of the WHPP on FL and DB, as well as the effect of FL DB over the measurement period of 18 months. We discovered substantial strong improvements for both FL and DB directly after the WHPP when compared to baseline using two random intercept linear mixed regression models. After 18 months, there were notable long-term improvements for FL and weak improvements for DB. Furthermore, across all measuring time points, FL had a significant

moderate influence on DB. We conclude that multicomponent WHPPs can result in sustained gains in FL and DB, and that FL can be seen as a valuable tool for increasing food-related knowledge and abilities as well as improving DB. This research closes a gap in current research on FL's effect on DB in WHPPs and lends credence to the notion of using FL to create WHPPs revolving around FL to enhance DB. Our results should pave the way to incorporate aspects of FL into existing WHPPs for OWs as well as to persuade funders to support future research on FL to develop WHPPs targeting this construct. Nevertheless, the impact of FL on DB, as per our findings, appears to be moderate, indicating that DB is influenced by various other factors. Indeed, scholars suggest an indirect correlation between FL and DB, which is shaped by individual values, food accessibility, and sociocultural influences, in addition to environmental factors like food availability and affordability. Therefore, future research should apply a more refined focus on the effect of FL on DB by incorporating these factors to understand the food choice of OWs within the respective environmental context.

Contribution:

Svenja Meyn was responsible for data curation and writing of the original draft. The latter was conducted in close exchange and correspondence with the other first-author. Simon Blaschke had the lead in the conceptualisation of the study and the investigation as well as project administration, refining and reviewing the first draft. Svenja Meyn and Simon Blaschke conducted the formal analysis together with Simon Blaschke developing the plan for the analyses. Filip Mess was responsible for conceptualisation, funding acquisition, project administration and reviewing.

5 Discussion

The discussion will firstly give a short summary of the studies' results concerning the respective research goals and give an initial integration of the findings within the current state of research. Then, the results will be discussed for each study individually in a more detailed context to gain knowledge for the development and adaption of WHPPs. Furthermore, the findings on the two domain-specific health literacy facets, PAHCO and FL, will be compared and interpreted. In addition, the discussion will present limitations of the studies and lastly give recommendations for future research and practice.

5.1 Summary of the Results

The present studies in general enrich the knowledge on health promotion in OWs, which is a relevant field of research on its own due to the proportion of working adults in this occupational group and its identified health demands. Beyond this the first study supported the assumptions of the first research goal, which investigated the connection of domain-specific health literacy and risk factors of NCDs, and found that the domain-specific health literacy facet of PAHCO shows a positive direct connection with MetS but no indirect connection between these two variables in the mediation with LTPA. These findings are in agreement with the study by Carl, Grüne, et al. (2020) who investigated the connection of PAHCO with HrQoL in apprentices and thus extends this previously reported connection to the objective health outcome of MetS in the occupational group of OWs.

The second study partially supports the assumptions of the first research goal. This study established that FL is connected with NAFLD in an indirect-only mediation model through DB. Although, FL and NAFLD showed no direct connection, these findings are partially in line with Haigh et al. (2019) who found that aspect of FL are facilitators for improvements in DB, which in return can moderate indicators of NAFLD. Accordingly, the indirect-only mediation of the second study aligns with previous research that separately investigated these connections. Prior studies have shown a positive relationship between FL and DB (Lee et al., 2023), as well as a health-enhancing relationship between healthy DB and NAFLD (Micha et al., 2017). In line with these studies, Hashemzadeh et al. (2022) established a connection between food insecurity and health indicators for NCDs by showing that lacking FL is connected to NAFLD.

The third study showed that PAHCO displayed sustainable long-term improvements following an in-person multicomponent WHPP and proved that the sub-competencies of PASR and CCPT showed a positive effect on the secondary outcomes over the measurement period of 18 months. These findings support the assumptions of the second research goal of this dissertation project and are in line with a currently released preprint on the changes of PAHCO following a digital three-month PAHCO intervention in OWs

(Oppermann & Dierks, 2024). In addition, the study by Oppermann and Dierks (2024) also displayed a significant connection between the sub-competencies of PAHCO and HrQoL, but this connection was not the primary aim of the preprint study and therefore only examined in correlational analyses.

In the fourth study, FL showed sustainable improvements following an in-person multicomponent WHPP and a positive effect of FL on DB, which is in agreement with the second research goal aimed at investigating the changeability and temporal stability of domain-specific health literacy facets. Although Begley et al. (2019) employed a different methodological design with a shorter follow-up period, the findings are in agreement with the current state of research on FL interventions in working aged adults and extend this current state by proving that long-term changes in FL might be achievable through WHPPs in the target group of OWs.

5.2 The Connection of PAHCO with PA and MetS

Investigating the connection of PAHCO with the behaviour related determinants of PA and MetS as a health indicator for NCDs is of great importance in general and workplace health promotion to quantify the potential of this determinant (Alavi et al., 2015; Caprara, 2021; Rahma et al., 2021) in the mitigation of NCDs. Furthermore, this investigation might inform the development of interventions on PA and MetS to prevent NCDs (Carl, Grüne, et al., 2021; Schmid et al., 2020). The findings of the first study display a direct connection between these two variables and thereby underscore the importance of PAHCO in connection with MetS by displaying a direct connection between these two variables. Moreover, the effect size found for this connection in the first study of this dissertation project is larger in comparison to studies investigating the link between health literacy and MetS. This is in favour of the practical value of this domain-specific health literacy facet, but could also derive from varying MetS prevalence rates due to differing populations in the studies compared (Cheng et al., 2018; Yokokawa et al., 2016).

In addition, the value of PAHCO is also highlighted in comparison to the connection between LTPA and MetS as these variables display no direct connection in the SEM analysis, while PAHCO and MetS are directly connected. This difference between PAHCO and LTPA in the connection to MetS might result for example from the cut-point bias of the employed questionnaire (Olds et al., 2019) or general inaccuracy of self-reported amount and frequency of LTPA at different intensity levels (Prince et al., 2008). This potential bias and inaccuracy might impair the assessment of this health behaviour and consequently could affect the connection between LTPA and MetS. Besides this methodological explanation, the difference in the connection between PAHCO and LTPA to MetS might as well derive from the fact that LTPA focuses on the quantity of LTPA, but largely neglects qualitative health-enhancing aspects of LTPA. This qualitative health-enhancing facet is

represented in the PAHCO model within the sub-competence of CCPT and paired with quantitative sub-competencies directly addressing health-enhancing PA (Carl, Grüne, et al., 2020; Sudeck & Pfeifer, 2016). In line with this argument, Holtermann et al. (2018) emphasise the importance of the qualitative aspects of LTPA, noting that extreme LTPA may lead to overtraining and could also negatively affect cardiovascular health. Thus, LTPA and PAHCO may have a different impact on MetS, which could confirm the value of this domain-specific health literacy facet in WHPPs.

Although this was not the primary aim of this study a strong connection between PAHCO as a domain-specific health literacy facet and LTPA was additionally detected, thus extending results of previous studies examining the connection of general health literacy with PA (Buja et al., 2020; Ishikawa et al., 2008). Such a connection between the domain-specific facet of PA and the respective health behaviour supports the value of domain-specific health literacy facets as valid and precise determinants for health behaviour and health outcomes in the prevention of NCDs. In summary, implementing the PAHCO model in WHPPs for OWs could boost their LTPA and thereby mitigate MetS. Additionally, WHPPs incorporating PAHCO can for example address PA by altering for example work-related PA behaviours. In detail, the motivational and volitional aspects of PASR may increase active breaks or walking meetings. Furthermore, CCPT can help OWs develop PA behaviours that counteract the occupational risk factors and address individual needs to promote health and reduce cardiovascular risk factors.

5.3 The Connection of FL with DB and NAFLD

To effectively promote health and prevent NCDs at the workplace, it is crucial to investigate its determinants and therefore examine the relationship between FL and the behaviour-related factors of DB and NAFLD as an important health indicator for NCDs (Clohessy et al., 2019; Lee et al., 2022; Romero-Gómez et al., 2023). This research quantifies the theoretical assumptions of these constructs and could help to discover and adapt strategies for WHPPs in the target group of OWs. The second study examines an indirect-only mediation model, which establishes a moderate connection between FL and DB and a small connection between DB and NAFLD, but no direct connection between FL and NALFD. Due to the lack of studies combining these constructs as well as largely varying study designs (Carroll & Rotman, 2023) and constructs in the existing studies the comparison of the effect sizes is difficult (Yasutake et al., 2014). Yet, at least for the connection between FL and DB current research seems in line with respect to the examined effect sizes (Amouzandeh et al., 2019).

This indirect-only mediation illustrates the complexity of the examined connections and the plethora of influences in the food environment on the individual's DB and even more so on NAFLD (Murakami et al., 2022). This complexity is supported by research suggesting

that even the connection between FL and DB is indirect with environmental and social factors amongst others affecting the relationship between FL and DB (Vidgen & Gallegos, 2014). For example, even individuals with high FL might face external barriers such as limited access to healthy foods, time constraints, cultural influences, or social norms that affect their dietary choices (Palumbo, 2016; Truman et al., 2017). Furthermore, the complexity of DB is illustrated by the food choice framework by Chen and Antonelli (2020). In this framework FL can be viewed as a cognitive factor of food choice in constant interaction with personal-state factors (e.g., food-related habits and experiences), which process food-internal factors (e.g., sensory features of food) and food-external factors (e.g., food information and environment) in the individual's cultural, economic and political context (Chen & Antonelli, 2020). The context of OWs can be prone to heavy work investment and work intensification, which are common conditions of office work and can lead to long working hours and skipping breaks and consequently impair healthy DB and promote the development of NAFLD (Lee et al., 2021). Lastly, FL and NAFLD might be indirectly connected as examined by the second study of the dissertation project due to numerous other influencing factors, such as genetics or other lifestyle factors (e.g., sedentariness) account for larger amounts of the explained variance (Stefan et al., 2019).

In contrast to the small effect sizes examined in studies looking at the relationship between general health literacy and DB (Buja et al., 2021; Mungvongsa et al., 2023), this study found a moderate connection between FL, as a domain-specific health literacy facet, and DB. The effect size of FL with DB in comparison to the research on this connection in general health literacy support the notion that FL is a reliable and accurate predictor of healthy DB in the prevention of NAFLD. In conclusion, adding the FL model to WHPPs for OWs may promote healthy DB and consequently reduce the risk of NAFLD. For instance, functional FL could help OWs make healthier food choices by recognizing the appropriate portion size and understanding the nutritional content of food in the employee canteen. Critical FL might reduce emotional eating in OWs during stressful occupational tasks and promote healthy snacking.

5.4 Long-term Changes in PAHCO and its Effect on LTPA and HrQoL

Testing the theoretical assumptions of changeability and temporal stability of PAHCO following a three-week in-person multi-component WHPP, which focused on health-enhancing PA, is essential for the development and adoption of WHPPs on this construct in the future. In line with this claim, WHPPs with an underlying theoretical framework and an empirical analysis of such frameworks are substantial predictors for the feasibility and effectiveness (Carl, Grüne, et al., 2021; Grønningsæter & Kiland, 2023). The present study observed as a part of this dissertation large long-term improvements in PAHCO following the WHPP over the measurement periods of 18 months. Furthermore, PASR and CCPT

displayed a small-to-moderate positive effect on HrQoL and PASR showed an additional small-to-moderate positive effect on LTPA. Although the intervention content varied between previously published reports and the third study of this dissertation project, the findings in general align by demonstrating relatively stable changes in PAHCO. For example in comparison to a digital WHPPs for health-enhancing PA in OWs or a review on physical literacy interventions in working adults (Carl et al., 2022; Oppermann & Dierks, 2024; Schorno et al., 2022). Yet, the present study examined larger effect sizes and investigated a longer follow-up period, which in particular highlights the changeability by a WHPPs as well as the temporal stability in the follow-up period (Oppermann & Dierks, 2024; Schmid et al., 2020; Schorno et al., 2022).

The comparatively larger effect size of the present study could be due to the high amount of direct personal expert feedback of the WHPP and a larger amount of guided health-enhancing PA session during the three-week in-person WHPP (about 2 hours of guided PA session/day) versus lower amounts of guided health-enhancing PA in the digital WHPP (about 10 minutes of guided PA/week) (Oppermann & Dierks, 2024). While the three-week in-person WHPP demanded a substantially higher deployment of human resources, the findings might imply a dose response relationship, which could indicate that a higher amount and duration of intervention sessions might result in larger PAHCO increments. In addition, the practical nature of the guided health-enhancing PA sessions and the theoretical instructions given by expert presentations during the three-week in-person WHPP could indicate a reciprocal connection between the promotion of PAHCO and the execution of health-enhancing PA. This reciprocal connection implies that higher PAHCO levels do promote the amount of the individual's health-enhancing PA, while PAHCO is also increased in parallel by conducting health-enhancing PA (Sudeck & Pfeifer, 2016).

The above mentioned findings demonstrate the value of this construct for health promotion in the workplace in particular for the target group of OWs. These results suggest that WHPPs addressing PAHCO could promote health-enhancing PA and HrQoL for example by the coupling of PASR and CCPT. Thereby PASR might ensure the continuous engagement in LTPA over time on the one hand, while CCPT might serve to review the respective LTPA content to evoke health-enhancing benefits from the conducted activities. Given the propensity of OWs towards insufficient PA and increased risks of MetS stable changes in PAHCO could significantly benefit this group by encouraging LTPA and altering work-related PA patterns. However, the examined three-week in-person WHPP was not designed around PAHCO and had a high demand of human resources in the delivery, which raises the importance of refinement and redevelopment of WHPPs precisely targeting this construct in the future.

5.5 Long-term Changes in FL and the Effect on DB

One of the main challenges in the modern world is empowering people to healthy DB in order to prevent NCDs in the general population (Qiao et al., 2022) and also in OWs (Clohessy et al., 2019). FL holds the potential to address this challenge in OWs within WHPPs, but current research has not targeted OWs specifically and is lacking follow-up periods beyond six months, which leaves the efficacy of FL for this population and the trait-like dispositions of this construct somewhat at question (Begley et al., 2019; Glympi et al., 2020; Ng et al., 2022). The present study found substantial long-term improvements of FL for OWs with a large effect size following an in-person multicomponent WHPP and showed that FL has a small-to-moderate influence on DB over the period of 18 months. However due to the reporting of the statistical analyses in the compared studies (Begley et al., 2019; Ng et al., 2022), the effect sizes cannot be adequately placed in the context of the existing literature. Yet, the review by Glympi et al. (2020) revealed similar effects on the outcome of DB by interventions focusing on dietary information, which is closely connected to the construct of FL.

Furthermore, our findings indicate, a slight positive trend in FL after completing the WHPP. This trend is partially in line with findings by Begley et al. (2020), who found increased FL levels for the subscale of food selection and preparation after a three month follow-up period. A potential explanation might be that improvements in FL during the WHPP period enable participants with an ideal foundation to facilitate for example better access to nutrition-related information during the follow-up period. In particular the interactive and critical facets of the theory on FL, which is founded in Nutbeam's health literacy model (Nutbeam, 2000), support this assumption by discussing food-related information in the respective social context and navigating barriers to healthy-DB in the food environment successfully (Krause et al., 2018). Yet, this is only a tentative assumption as in line with Begley et al. (2020) DB levels decreased significantly after completion of the intervention and the analysis revealed FL showed no interaction with DB in the follow-up period, but a constant effect over the measurement period.

These results highlight the potential of FL for WHPP, especially for the target group of OWs. Enhanced FL can, for instance, enable OWs to prefer nutrient-dense snacks like fruits and nuts over processed, high-sugar options, improving their overall DB and potentially also have a positive effect on colleagues at the workplace by the peer social support of FL champions, which could serve as a feasible strategy to manage barriers in WHPP (Torquati et al., 2018). Although the findings of this study are in line with previous FL studies in working aged adults and extend the current state of knowledge by implementing a longer follow-up period the intervention content of these programmes varied to a great extent, which makes precise recommendations on WHPPs targeting FL difficult.

5.6 Comparison of the Findings on PAHCO and FL

In the comparison of the cross-sectional studies, which examine the first research goal investigating the connection of domain-specific health literacy, health behaviour and health outcomes it first of all has to be noted that the connection between PAHCO and LTPA is larger than the connection between FL and DB. This difference in the effect sizes could be due to the fact that PAHCO and as a result LTPA have direct immediate positive benefits for the individual, such as improved mood (Chan et al., 2019), which might reinforce the behaviour and reciprocally also the domain-specific health literacy facet. This immediate reinforcement process between FL and healthy DB might not be present as differing DBs show no immediate effect for example on metabolic stress (Parcina et al., 2014) and healthy DB is often more future-focused, whereas unhealthy DB is often linked to immediate reward, for example in taste (Kruse et al., 2024). Since PAHCO might be more strongly connected to LTPA in comparison to FL and DB, one might speculate that LTPA and the recommendations on this health behaviour might be easier to achieve than the execution of healthy DB, which requires knowledge in the acquisition of healthy food and skills in food preparation (Chae et al., 2013; Mostafazadeh et al., 2024).

Secondly, next to this difference in the studies, PAHCO exerts a direct effect on the prevalence of MetS, while FL is only indirectly connected to NAFLD mediated by DB. This indirect connection of FL with NAFLD in the mediation by DB might be explained by the qualitative score for healthy DB obtained by the FFQ instrument employed for DB (Winkler & Döring, 1998). This qualitative measurement using a FFQ is methodologically different from the assessment employing the LTPA questionnaire (Godin & Shephard, 1985), which accounts for the amount of LTPA at different intensities and does not contain a qualitative element. Such a qualitative element, however, is a central component of PAHCO, which is represented by the sub-competence of CCPT (Sudeck & Pfeifer, 2016). In addition to this conceptual methodological argument, LTPA and MetS possibly do not show any direct connection in the mediation model because not all forms of LTPA necessarily contribute to health enhancements, which in particular holds true for extreme forms of PA and cardiovascular health (Eijsvogels et al., 2018). Furthermore, FL and NAFLD might only be indirectly connected as a multitude of social and environmental factors influence the connection between FL and DB (Mostafazadeh et al., 2024). In comparison to the social and environmental factors for LTPA, which are often benefitting for example by access to facilities in the residential area (Shibata et al., 2009), FL is more difficult to translate into healthy DB and consequently health with barriers, such as limited access to healthy foods, time or financial constraints (Zavala et al., 2022). Therefore, the first and the second study of this dissertation project could indicate differing patterns between domain-specific health

literacy, health behaviour and health indicators for NCDs due to methodological, conceptual and social environmental factors.

Lastly in the comparison of the studies addressing the first research goal it has to be mentioned that the health outcomes of MetS and NAFLD are only to some degree comparable (Kim et al., 2014). Some researchers argue that NAFLD is the hepatic representation of MetS and share common risk factors, such as obesity, insulin resistance, dyslipidaemia, and hypertension, which strengthens their association (Smits et al., 2013). Whereas other researchers postulate that NAFLD should not be viewed as a part of MetS, but rather as a distinct entity, which is supported by data indicating that NAFLD, regardless of MetS, contributes to endothelial dysfunction and accelerated atherosclerosis (Kim et al., 2014; Villanova et al., 2005). Even though MetS and NAFLD might be distinct from each other researchers agree that both risk factors for NCDs are strongly connected with research indicating that the prevalence of NAFLD among individuals with MetS is about 80% (Parvanescu et al., 2021; Pouwels et al., 2022; Radu et al., 2023). These notions strengthen the comparability of the objective health outcomes employed.

Concerning the longitudinal studies addressing the second research goal, PAHCO and FL, first of all, display similarly large effects during the multicomponent in-person WHPP. With respect to the distribution of the session content during the WHPP, about 70% of the sessions focused on the domain of health-enhancing PA with the remaining percent being equally distributed between topics surrounding healthy DB and mental health. Therefore, one might expect that PAHCO would display a larger effect size compared to FL. However, some authors argue that health behaviours are interconnected (Oftedal et al., 2019) and content on health-enhancing PA might function as a gateway for changes in DB. Moreover, some researchers argue that a spill-over effect induced by interventions focusing either on PA or DB will trigger a behavioural shift towards the respective other health behaviour (Foster-Schubert et al., 2012; Halliday et al., 2014). Furthermore, the multicomponent in-person WHPP also tried to target DB by providing recommendations for portion sizes and recipes at every meal over the three-week period, which might have had an impact on FL in addition to the guided input on this topic (Macdiarmid et al., 2013). In summary, the effect sizes of PAHCO and FL might have been similar due to potential spill-over effects or passive intervention components, which may have accounted for the difference in the overall proportion of the respective intervention components.

Secondly, the differing trends in the follow-up period between PAHCO and FL over the course of 18 months have to be noted. In this comparison, FL shows a slight non-significant increase after completing the intervention to the first follow-up measurement after six months. This trend is in line with the PAHCO subscales of CCPT and PAAR, but deviates from the trend of the PASR subscale, which displays a decreasing trend. PASR comprises

motivational and volitional determinants for consistent engagement in health-enhancing PA (Sudeck & Pfeifer, 2016). While research on this PAHCO subscale has not been conducted to the knowledge of the author, studies indicate that PA motivation may decline during the follow-up period (Samdal et al., 2017; Teixeira et al., 2012). However, the review by Teixeira et al. (2012) postulates differing patterns in PA motivation depending on the content during the intervention. In line with this, in particular the behaviour change techniques of goal setting, self-monitoring, and motivational interviewing were effective intervention strategies to maintain PA motivation during follow-up periods (Larsen et al., 2020). These findings could inform the adaption of the present multicomponent in-person WHPP to further ensure the sustainment of PASR in the follow-up period.

Lastly, the effect sizes of PAHCO on LTPA and FL on DB were small-to-moderate in the longitudinal studies. These effects are in line with a review by Sweet and Fortier (2010), which reports that interventions focusing on PA and DB show smaller effects on the health behaviour level in comparison to interventions targeting a single health behaviour, but larger effects on health outcomes. This review underlines the validity of the investigated effects of domain-specific health literacy on health behaviour. Unfortunately, the studies addressing the second research goal cannot be compared with respect to the effect of domain-specific health literacy because in the longitudinal study on FL the health outcome of HrQoL was not employed in the analysis due to lacking resources in the manuscript design.

5.7 Limitations of the Studies

Although the research of this dissertation project presents valuable insight into the associations and the effect of domain-specific health literacy facets in WHPP, these studies come with methodological and project-related limitations, which need to be considered.

Concerning the methodological limitations, the PAHCO questionnaire employed did not examine Movement Competence as a sub-competence of the postulated theoretical model due to difficulties in the operationalisation of this sub-competence, which therefore was not included in the available questionnaire at the time of the data collection (Sudeck & Pfeifer, 2016). Although this sub-competence is contained in the updated version of this questionnaire (Carl, Sudeck, et al., 2021), the results of this dissertation project can only be compared to respective PAHCO aspects of the updated PAHCO questionnaire. Along with this limitation, the FL measure by Gréa Krause et al. (2018), which was used in this dissertation project, has a narrow person-oriented understanding in comparison to other questionnaires of this construct. This questionnaire largely neglects environmental aspects of FL and comprises only two out of the four domains of the FL definition by Vidgen and Gallegos (2014) (Amouzandeh et al., 2019). This narrow understanding of FL needs to be extended in future research, this measure, however, was the only validated German questionnaire available and suited the focus on personal factors of DB.

Furthermore, LTPA was assessed by a self-report measure, as published by Godin and Shephard (1985). On the one hand, LTPA might differ from health-enhancing PA due to for example due to risky and extreme forms of PA during leisure-time (Eijsvogels et al., 2018) and on the other hand, it is influenced by recall and social desirability bias (Prince et al., 2008). Employing objective PA measures could account for these biases and additionally assess sedentariness, which presents a crucial issue in OWs along with the lack of PA (Celis-Morales et al., 2012; Huang et al., 2019). In line with the inaccuracy of the self-report assessment of LTPA, DB was examined in the second study with a self-report FFQ, which can be prone to similar measurement errors as the employed FFQ for example does not specify portion sizes or pictures in the assessment of the respective food group intake (Kirkpatrick et al., 2019; Winkler & Döring, 1998). This inaccuracy in the measurement of DB seemed difficult to circumvent because of the comparably lower test efficiency of the DB assessment alternatives, such as 24-hour dietary recall measures (Kirkpatrick et al., 2019). Furthermore, the employed FFQ showed good criterion validity in our studies in line with the current literature on FL and NAFLD (Gréa Krause et al., 2018; Yasutake et al., 2014).

Lastly, the longitudinal studies of this dissertation project did not include implementation parameters, which were examined qualitatively and in part, were also published by Pelster et al. (2022), but not included in the analyses. This limitation is crucial as implementation parameters can provide essential context regarding how, where, and under what conditions an intervention was delivered. Therefore, the lack of implementation parameters can challenge the understanding of factors contributing to the respective intervention outcomes limiting the ability to draw meaningful conclusions. Incorporating implementation parameters into the analysis of effectiveness allows researchers and practitioners to gain a more comprehensive understanding of how and why interventions work and can thereby lead to more effective and replicable outcomes (Hasson, 2010). This limitation could only be accounted for to a small degree, but the implementation environment of the WHPP remained stable throughout the data collection period, e.g. with the same experts delivering the WHPP during the data collection period.

With respect to the project-related limitations, the longitudinal studies have implemented neither a control group nor randomisation in the third and the fourth study. As a result, the causal evidence about how the intervention affected domain-specific health literacy, health behaviour and health has to be viewed with great caution. Although numerous organisational and logistical issues can hinder the implementation of a controlled design in occupational research (Engbers et al., 2005), as it was the case in these studies, randomised control trials are necessary to measure the impact of PAHCO and FL on health-enhancing PA and healthy DB respectively without the possibility of observation bias

(Hamre et al., 2008). Unfortunately, the limitation with respect to employment of a control group could also not be addressed in the study on PAHCO in OWs by Oppermann and Dierks (2024), although this was the initially planned in the study protocol (Oppermann & Dierks, 2023). This limitation with respect to the second research goal was tried to contain by examining a longer measurement period in comparison to previous research, which allows for the observation of natural fluctuations and the differentiation between short-term and long-term effects of an intervention (Welten et al., 2018).

Furthermore, the three-week in-person WHPP did not explicitly integrate PAHCO and FL in the content of the intervention sessions. By not directly incorporating these domain-specific health literacy model, the programme may have missed opportunities to effectively enhance participants' PAHCO and FL. Consequently, this omission could limit the programme's efficacy in achieving lasting improvements in domain-specific health literacy, as the intervention session content of the WHPP might have addressed deviating aspects in the aim to promote employees' health. The judgement of this omission was additionally complex because the provided intervention descriptions could have been partially outdated, as the information for the research team did on some occasions diverge from the description of the session content by the experts in the interviews. Future iterations of the programme should, on the one hand, consider embedding domain-specific health literacy in the intervention session to ensure a more holistic and effective approach to workplace health promotion. On the other hand, the experts of the WHPPs should review the documents to describe the intervention sessions, where a deviation occurred to increase the replicability of the WHPP.

5.8 Recommendations for Future Research

The findings of this dissertation project underline the relevance of domain-specific health literacy for health promotion at the workplace particular for OWs as a means to mitigate risk factors of NCDs. To deduce scientific recommendations on domain-specific health literacy, precision prevention in WHPP, which aims to provide the right intervention to the right person at the right time in the context of work (Mess et al., 2024), offers interesting connecting points for future research on these constructs in OWs. With this scientific approach in mind and in line with multicomponent WHPP addressing both PA and DB (Tam & Yeung, 2018), the combination of PAHCO and FL might offer the potential to precisely assess health determinants and subsequently develop personalised WHPPs while simultaneously implementing social and environmental factors for NCDs.

First, the precision prevention approach in the research on domain-specific health literacy could identify needs on the sub-competence level of domain-specific health literacy and vulnerable groups at the office environment by using mixture-modelling analyses to inform occupational health and safety stakeholders and guide the adoption and

development of WHPPs (Basińska-Zych & Springer, 2021). Future research on the domain-specific health literacy facets of PAHCO and FL might for example employ latent profile analysis (Friedrich et al., 2023) or phenotyping approaches (Burgermaster & Rodriguez, 2022) on these constructs and other relevant indicators to demonstrate that certain groups of OWs displays low levels on the sub-competencies of PASR and functional FL. These findings should then be lined-up with current knowledge of health experts, the aims of existing WHPPs and the underlying strategy of occupational health and safety measures to prevent NCDs.

Second, these empirical insights on domain-specific health literacy facets and relevant target groups could be used to adapt or develop personalised multicomponent WHPPs in a co-creation approach by directly involving the examined target group and other relevant stakeholders as well as the findings of mixture-modelling analyses (Longworth et al., 2024). This approach for future research can offer numerous benefits for WHPPs targeting OWs including enhanced relevance, increased engagement and improved effectiveness of these programmes (Leask et al., 2019). For example, participatory workshops involving OWs could gather insights and collaboratively design personalised multicomponent WHPPs concerning sub-competencies of PAHCO and FL, which were identified as relevant determinants for changes in health behaviour from an empirical and participatory perspective (Heimburg & Cluley, 2021). Furthermore, such workshops may serve as platforms where employees can express their needs, preferences, and ideas regarding the implementation and personalisation of WHPPs to develop tailored strategies towards single or multiple tailoring aspect of the interventions, such as just-in-time-adaptive interventions (Ismail & Al Thani, 2022). Next to these benefits, the co-creation approach could also offer insight into the development of domain-specific health literacy in the future, as experts on WHPP might provide practical ideas to for example integrate or extend PAHCO on a holistic perspective (Carl, Grüne, et al., 2021).

Third, FL and PAHCO need to be paired and tested rigorously on an environmental perspective as this dissertation project and most of the current research, in particular on PAHCO (Carl et al., 2021), has employed a strong personal focus. The integration of domain-specific health literacy into holistic health frameworks, such as the socio-ecological model, would allow for a comprehensive understanding of how these facets interact with environmental determinants to influence health-promoting behaviours (Carl et al., 2021). Moreover, future studies should explore the potential benefits of introducing a new sub-competence to PAHCO and FL, such as a "socioecological competence," which focuses on managing and adapting to environmental demands of the respective health behaviour. These efforts could help to enhance the explanatory power of domain-specific health literacy and provide a more holistic approach to promoting physical activity and health (Carl

et al., 2021; Lisciani et al., 2024). Within these steps for future research, empirical validation of these sub-competencies would be crucial to ensure their practical applicability in diverse settings and populations.

Finally, these insights on the development of personalised multicomponent WHPPs on domain-specific health literacy following a co-creation approach need to be tested by future research examining their implementation and effectiveness. Concerning the implementation and effectiveness of these WHPPs future studies should investigate these domain-specific health literacy facets along with implementation indicators in randomised controlled trials with multiple follow-up measurements to understand the long-term efficacy, identifying trends and patterns, elucidating mechanisms of change, capturing response variability, and evaluating cost-effectiveness (Geller et al., 2017; Rosen et al., 2006). This goal for future research is underlined for example by the current research displaying that the study by Oppermann and Dierks (2024) and the studies of this dissertation project on PAHCO could not accomplish a randomised controlled design. Furthermore, in this interplay of implementation and effectiveness indicators of personalised multicomponent WHPPs following the precision prevention approach with a holistic health perspective, coincidence analysis presents a powerful statistical analysis to uncover and understand complex causal relationships in data (Baumgartner & Thiem, 2015). Coincidence analysis is a systematic way to analyse and interpret the interplay of multiple indicators leading to improvement in domain-specific health literacy, health behaviour and consequently health identifying different combinations of indicators that contribute to effective health gains and thereby providing a clearer understanding of how various elements interact (Roczniewska et al., 2023). For example, the interaction of low levels of CCPT and critical FL could lead to the development and execution of a weekly meal plan that supports and adapts the content of health-enhancing PA session, which consequently has a greater effect on HrQoL or cardiovascular risk factors.

5.9 Practical Implications of this Dissertation

The findings from the dissertation project suggest several practical implications for WHPPs as well as occupational health and safety experts targeting OWs to enhance domain-specific health literacy with the overarching aim to prevent NCDs. Although this thesis provides potential implications for practice in WHPPs, the author notes that implementation in a participatory process is needed (Harting et al., 2022).

The research highlights the importance of incorporating PAHCO and FL into WHPPs by including practical and theoretical components that precisely address these domain-specific health literacy facets on the subscale or sub-competence level among OWs. This implication is supported by the examined long-term changes of PAHCO and FL following the three-week in-person multicomponent WHPP and the effect on health behaviour over

the period of 18 months. This implication could for example be transferred in a workshop format with a focus on improving OWs' understanding of PAHCO and FL. Yet, this implication is not limited to the development of new WHPPs, but could also be transferred to existing programmes by adapting elicited components, such as the language and wording of leaflets or digital reminders before or after a WHPP to align with PAHCO or FL.

In addition, the findings from the dissertation project on domain-specific health literacy and their influence on health behaviours and outcomes in OWs could also have significant implications for organisational health checks and screenings. The questionnaires of PAHCO and FL might be integrated in organisational health checks thereby allowing for a more comprehensive assessment of determinants for OWs' health behaviour and health. In combination with the assessment of health behaviour and health, these domain-specific health literacy facets could offer starting points for practitioners' recommendations and subsequent personalised WHPPs. Furthermore, the assessment of PAHCO and FL in occupational health checks and screenings could inform the communication between practitioner and OW to ensure efficient communication and a high compliance.

Therefore, occupational health and safety experts, such as practitioners and staff of occupational health checks, should receive comprehensive training in their communication strategies in accordance with the domain-specific health literacy models of PAHCO and FL. Implementing PAHCO and FL in the patient-practitioner communication can significantly improve the effectiveness of health promotion efforts and WHPPs. For instance, could equipping these experts with the skills to effectively communicate the importance of PAHCO and FL, improve the employees' understanding and management of their own domain-specific health literacy. In addition, integrating PAHCO and FL into the training curricula of occupational health and safety experts ensures that they are prepared to address the diverse needs of employees, ultimately leading to improved health outcomes and enhanced workplace well-being.

Lastly, the results indicate that sustained improvements in PAHCO and FL can be achieved by a multicomponent in-person three-week WHPP with a high amount of guided interventions sessions. This underscores, on the one hand the need for extended intervention sessions in WHPPs, rather than brief programmes, with an extensive amount of in-person expert guidance during the programme. On the other hand, the findings suggest that a one-size-fits-all approach may not be effective as the initial health screening at the start of the WHPP and the high amount of expert guidance allowed a partially personalised session content to address the specific needs related to both physical activity and dietary behaviours. Blended WHPPs containing both digital and in-person components could present a fruitful strategy to effectively personalise WHPPs, while also providing guided expert feedback (Sun et al., 2020).

6 Conclusion

This doctoral thesis aimed to explore the intricate relationships between domain-specific health literacy, particularly PAHCO and FL, and the health behaviour of LTPA and DB on the cardiovascular risk factors of HrQoL, MetSSS and NAFLD among OWs by employing studies with cross-sectional and longitudinal designs.

These studies revealed significant contributions to the current research by examining both direct and indirect health-enhancing connections of domain-specific health literacy with objective health outcomes, representing major risk factors for a large number of NCDs in OWs, as analysed by complex statistical calculations of structural equation and path modelling. The studies methodologically extend previous longitudinal research to the target group of OWs. By employing multiple follow-up measurements over the period of 18 months, long-term improvements of PAHCO and FL and a lasting positive effect on health behaviours could be demonstrated in OWs, which are at particular risk for NCDs.

Thus, these findings provide significant contributions to the current research and might serve as a connecting point for future research for example with a focus on precision prevention approaches to promote domain-specific health literacy or mixture modelling analyses to identify needs on the subscale or sub-competence level as well as to examine vulnerable groups. Finally, practical implications from this thesis could inform the integration of PAHCO and FL in occupational health checks to guide personalised health recommendations and shape the interaction between OWs and practitioners.

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8 List of Publications

Publications are listed in chronological order (starting with the lastest):

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