Chapter 8

General discussion
The research in this thesis was conducted as part of the Determinants of Diet and Physical Activity (DEDIPAC) Knowledge Hub¹ and focused on two health-related behaviours: physical inactivity (i.e. not being regularly active) and sedentary behaviour (i.e. sitting too much or too long). Since less is currently known about sedentary behaviour than physical activity, most studies in this thesis focused on sedentary behaviour. Insight in the proportion of the population that can be defined as inactive and/or sedentary (the ‘prevalence’) and what factors are associated with these behaviours (the ‘correlates’) can help monitor and compare population levels, identify and target inactive and/or sedentary populations, and evaluate public health strategies. As the current knowledge base is limited, the aim of this thesis was to use existing data to assess the prevalence and correlates of sedentary behaviour and physical activity of European adults, answering four research questions:

- What is the prevalence of sedentary behaviour in European adults?
- What is the prevalence of physical activity in European adults?
- What are correlates of sedentary behaviour in European adults?
- What are correlates of physical activity in European adults?

This general discussion will discuss findings relating to these questions, first summarising and discussing the findings with regards to the prevalence, followed by the findings relating to the correlates. Subsequently, it will discuss methodological issues of the studies included in this thesis, and the implications and recommendations for both research and practice. Finally, this thesis will be completed by some overall conclusions.

Prevalence

As stated in the general introduction, the term ‘prevalence’ refers to the proportion of a population that complies to a certain condition, for example accumulating more than seven sedentary hours per day or not meeting the physical activity recommendations. Prevalence data is needed to monitor and compare population levels, and to evaluate interventions and policies.

Prevalence of sedentary behaviour

The prevalence of sedentary behaviour in European adults was studied in a systematic literature review (chapter 2), the Eurobarometer survey (chapter 4) and the accelerometer pooling study (chapter 5). In addition, recent trends in the population levels of sitting time in Australian adults were studied using the Australian Health Surveys (chapter 6), while the differences among different ethnic groups living in the city of Amsterdam, the Netherlands, were compared in the HELIUS study (chapter 7). The results of these studies are summarised and discussed below.

¹ DEDIPAC Knowledge Hub: Determinants of Diet and Physical Activity Knowledge Hub.
According to the results derived from the 2013 Eurobarometer survey (chapter 4), the median sitting time of European adults was five hours per day, and 18.5 percent reported to sit more than 7.5 hours per day. This number varied greatly between countries, with 9 percent of the Spanish respondents reporting to sit more than 7.5 hours per day, compared to 32 percent of the Dutch. In general, adults in the north of Europe seemed to report more sitting time than those in southern European countries. These results were similar to the 2005 Eurobarometer survey.²

Even though the Eurobarometer surveys provide the opportunity to study the prevalence - as well as a range of potential correlates - of sitting time of adults across Europe, they have several disadvantages, including the use of self-reported sitting time. As subjective measures such as self-report are known to underestimate sitting time, it is likely that the levels of sitting time reported in the Eurobarometer survey are lower than the actual population levels of sitting time. In addition, possible linguistic differences in the interpretation of the questionnaire and cultural differences in responding to the questions might complicate comparisons between countries.

In order to summarise and compare all existing studies that provided sedentary behaviour prevalence data in European adults, a systematic literature review was conducted (chapter 2). This review aimed to provide an overview of all cross-European studies that measured sedentary behaviour in adults, to describe the (variation in) population levels according to these studies, and to discuss the impact of the assessment methods. This resulted in an overview of twelve articles, six of which were based on Eurobarometer surveys. These Eurobarometer surveys were the only studies that included a large number of European countries and thus provided the opportunity for cross-European comparisons. However, in view of the limitations of the Eurobarometer surveys, including the use of self-report measures mentioned above, the validity of these prevalence results is likely to be limited. Therefore, it was concluded that population levels of sedentary time in European adults are currently largely unknown. This demonstrates the need for standardisation and/or harmonisation of measurement methods in cross-European studies, preferably using a combination of objective (to increase validity and comparability) and subjective (adding behavioural context) measures.

In a first attempt to harmonise objective measures of sedentary time across Europe, national accelerometer data from four European countries (England, Norway, Portugal and Sweden) were pooled, harmonised and re-analysed (chapter 5). According to this data, participants accumulated an average of almost nine hours of sedentary time per day, and 20 percent of the participants were sedentary for more than 10 hours per day. These numbers were substantially higher than the results from the Eurobarometer survey, and comparable to the 2005/06 American NHANES accelerometer study.³ Norwegian adults showed the highest levels of sedentary time per day, followed by adults in England, Sweden and Portugal. This study showed
the added value of pooling, harmonising and re-analysing accelerometer data to increase comparability across studies, as well as the need for objective measures of sedentary time. However, remaining differences in sampling strategies and data collection, as well as the small number of countries with available population-based accelerometer data, still limited the opportunity for true cross-European comparisons.

Prevalence in Australia
Across all three Australian Health Surveys, respondents reported an average of six hours of combined occupational and leisure sitting time per day (chapter 6). In addition, the proportion of respondents accumulating ≥7 hours of sitting time per day was 38 percent in 2007/08, 39 percent in 2011/12 and 42 percent in 2014/15. Even though different questionnaires were used, this might imply that Australian adults sit more than adults in Europe (where 19 percent reported to sit >7.5 hours per day). Especially when taking into account that transportation sitting time was not included in the Australian Health Surveys, while this is an important source of sitting time for Australians. The proportion of respondents accumulating ≥7 sitting hours per day increased over time, and especially in 2014/15. This finding is in contrast with results of a longitudinal study by Milton and colleagues using the 2002, 2005 and 2013 Eurobarometer surveys, which indicated a decrease in self-reported sitting time.4 This discrepancy demonstrates the need for continuous (international) monitoring of population levels of sedentary behaviours.

Prevalence among ethnic groups
When examining the levels of objectively measured sedentary time in five ethnic groups living in the city of Amsterdam, the Netherlands (chapter 7), gender- and age-adjusted levels ranged from over 9 hours per day in participants from a Moroccan and Turkish origin to over 10 hours per day in participants from a African Surinamese origin. These differences between ethnic groups were not statistically significant. However, it is likely that more active and less sedentary people were more willing to participate in this study and wear the accelerometer, resulting in more homogeneous ethnic groups in the study than in real life, possibly concealing differences in sedentary time between the ethnic groups. Therefore, more insight into the levels of sedentary time in different ethnic groups is needed, preferably using population representative samples.

Prevalence of physical activity
To assess population levels of physical activity in European adults, a similar systematic literature review was performed as for sedentary time, again aiming to provide an overview of the existing studies, describe the reported population levels, and discuss the assessment methods (chapter 3). Twenty-five articles were included, reporting on sixteen different studies, which showed substantial variation in the assessment methods and reported outcomes, and consequently in the
presented population levels of physical activity. For example, seven distinct ways were identified to define if participants met the physical activity recommendations, and this percentage ranged from 7 to 96 percent across studies and countries. Taking into account the lack of objectively measured physical activity, this means that the population levels of physical activity in European adults are currently largely unknown. This shows the need for standardisation and harmonisation of (objective) measurement methods in cross-European studies.

Physical activity was also included in the study that pooled, harmonised and re-analysed national accelerometer data from England, Norway, Portugal and Sweden (chapter 5). Participants accumulated a mean of 36 minutes of moderate to vigorous physical activity per day, and 72 percent did not meet the physical activity recommendations of 150 minutes of moderate to vigorous activity per week in ≥10-minute bouts. These numbers are substantially higher than previous studies reporting that approximately 35 percent of the European adults did not meet the physical activity recommendations. This is in line with a recent study by Steene-Johannessen and colleagues, reporting moderate agreement between self-reported and objectively measured population levels of physical activity, advocating caution in the interpretation of self-reported surveillance data. Although high, the observed numbers are still lower than in the 2003/04 American NHANES accelerometer study, reporting that up to 97 percent of the American participants did not meet the recommendations. It should be noted, however, that the physical activity recommendations were (mainly) based on research with self-reported physical activity, meaning that objectively-measured physical activity might not correspond well to the current recommendations. In the pooled accelerometer data, England showed the highest levels of physical inactivity, followed by Portugal, Sweden and Norway. While the opportunity for cross-European comparisons was still limited by differences in study design, as well as the small number of countries with population-based accelerometer data, the pooling approach did demonstrate increased comparability across the included studies.

Prevalence of being sedentary and inactive
Recent studies suggest that individuals that are both inactive and highly sedentary might be at greatest risk for all-cause and cardiovascular mortality. This combination of behaviours was studied in the accelerometer pooling study (chapter 5) and the Australian Health Surveys (chapter 6). In the accelerometer pooling study, 9 percent of participants were classified as sedentary and inactive, defined as accumulating 10 or more sedentary hours per day and not meeting the physical activity recommendations of 150 minutes of moderate to vigorous physical activity per week. This percentage was higher in Norway and England (11 percent), than in Portugal (7 percent) and Sweden (5 percent). In the Australian Health Surveys, participants were defined as sedentary and inactive if they reported ≥7 combined occupational and leisure sitting

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hours per day and <30 minutes of leisure-time moderate to vigorous physical activity per week. Fifteen percent of the respondents met these criteria, and this number slightly increased over time. As the combination of high sitting time and low physical activity levels has not been studied extensively before, and different studies used different measurement methods and definitions, it is difficult to compare results. Therefore, this combination of behaviours should be studied more extensively, using a standardised operationalisation. The current numbers suggest that 5-15 percent of the adults might be defined as sedentary and inactive.

Conclusions regarding the prevalence of sedentary behaviour and physical activity
Given the lack of appropriate studies of sedentary behaviour, the large variation in reported physical activity levels, and the scarcity of data on the combination of being sedentary and inactive, the actual population levels of sedentary behaviour and physical activity in European adults are currently largely unclear and incomparable. The substantial differences between the harmonised accelerometer data and studies based on self-report might indicate that surveillance based on self-report measures indeed tend to underestimate sedentary time and overestimate physical activity population levels. Based on these harmonised accelerometer data in four European countries, 20 percent of European adults might be highly sedentary, 70 percent might not meet the physical activity recommendations, and around 10 percent might be defined as sedentary and inactive. In addition, levels of sitting time in Australian adults might be even higher and increasing over time, while there was no evidence for differences in sedentary time across different ethnic groups in Amsterdam. Regardless of the exact numbers, all studies in this thesis reported high population levels of sedentary time and/or physical inactivity in adults. In view of the health consequences of these behaviours, this demonstrates the need for interventions and policies aiming to increase physical activity and decrease sedentary behaviour.

Correlates
As explained in the general introduction, the term ‘correlate’ refers to a variable that is meaningfully and statistically associated with an outcome, such as physical inactivity or sedentary behaviour. Insight in who are sedentary and/or inactive can help identify and target those individuals at risk, while insight in why they are sedentary and/or inactive can inform the development of interventions and policies aiming to increase physical activity and decrease sedentary behaviour. Physical activity and sedentary behaviours are influenced by multiple (interrelated) correlates on the individual, social, organisational, environmental and policy levels, which are often described by socio-ecological models.\textsuperscript{12}
Correlates of sedentary behaviour

The correlates of sedentary behaviour were studied in the Eurobarometer survey (chapter 4), the accelerometer pooling study (chapter 5), the Australian Health Surveys (chapter 6) and the HELIUS study (chapter 7). The Eurobarometer survey as well as the Australian Health Surveys included a large range of socio-demographic and lifestyle-related potential correlates and analysed their associations with self-reported sitting time. Even though the five studies that were pooled in the accelerometer pooling study also included a range of potential correlates, only four variables (gender, age, weight status, and educational level) were included in all studies and could thus be harmonised and analysed. In the HELIUS study, a smaller amount of socio-demographic and lifestyle-related potential correlates were included. The latter study only identified physical activity to be a statistically significant correlate of sedentary time. The lack of more statistically significant correlates may be due to the small number of participants in each ethnic subgroup, limiting the statistical power. The studies included in this thesis commonly included gender, age, socio-economic status (based on education, occupation and/or income), weight status, physical activity and marital status as potential correlates of sedentary behaviour. The findings relating to these correlates are discussed below.

With exception of the HELIUS study, all studies in this thesis identified gender as a correlate of sitting time or sedentary time, and all studies reported that men were more sedentary than women. While these findings are in line with the 2002 and 2005 Eurobarometer surveys, systematic literature reviews reported less consistent results regarding gender and sedentary time. A possible explanation for these inconsistent findings was formulated after Lakerveld and colleagues conducted Chi-squared Automatic Interaction Detection (CHAID) analyses on the 2013 Eurobarometer data. These analyses, aiming to distinguish subgroups with higher (or lower) likelihood of engaging in prolonged sedentary time, showed that the association between gender and sedentary time differed within different socio-demographic subgroups. In some groups men were more sedentary than women, but in other groups this was reversed. If the association between gender and sedentary time is indeed moderated by other socio-demographic characteristics, the inconsistencies in the literature might be explained by socio-demographic differences in the populations under study.

With regard to age, the studies in this thesis demonstrated mixed results. The Eurobarometer survey showed an inverse overall trend for age and sitting time, the accelerometer pooling study showed that older participants (67-75 years) had higher levels of sedentary time than participants aged 20-35 years, the Australian Health Surveys showed that participants aged 55-74 years had lower levels of sitting time than young participants (15-34 years), and the HELIUS study showed no association. Previous Eurobarometer surveys reported that younger people sat
more, while the systematic literature reviews by Rhodes and colleagues and O'Donoghue and colleagues reported ‘extremely mixed’ results for the associations between age and sitting time\textsuperscript{14} and a mix between positive associations and no association between age and sedentary time.\textsuperscript{15} A possible explanation for these mixed results might be that sedentary time is more strongly associated with daily activities than age itself. For example, young adults that are still in school might be more sedentary than their peers with blue collar occupations, but less sedentary than their peers with white collar occupations. And later in life, retirement might provide more freedom in the daily activities, which can both result in more physically activity, as well as more sedentary activities, depending on personal preferences. This hypothesis might be supported by the fact that in the Eurobarometer survey, age was shown to be associated with sitting time in the model adjusted for educational level, but not in the model adjusted for current occupation, which is arguably a more direct indication of daily activities.

High socio-economic status (based on education, occupation and/or income) was consistently and strongly associated with sitting time or sedentary time in all studies except the HELIUS study (where no association was found). In the Eurobarometer survey as well as the Australian Health Surveys, the associations between socio-economic status and sitting time were the strongest identified. This positive association is (mostly) in line with previous Eurobarometer surveys and the systematic literature reviews.\textsuperscript{2,13-15} This may be a counter-intuitive result, as people with higher socio-economic status often display healthier lifestyle behaviours (e.g. healthier diets, less smoking, more physical activity) than people with a lower socio-economic status. The association between occupation and sedentary time is presumably the most direct, as people with sedentary occupations (e.g. desk-jobs) accumulate a large amount of sedentary time on a daily basis. Occupation, education and income are related, as sedentary occupations often require higher educational levels and generally provide higher incomes.

The association between weight status and sedentary time was assessed in all studies except the Eurobarometer survey. In both the accelerometer pooling study and the Australian Health Surveys, people with a higher BMI were more likely to be sedentary, while the HELIUS study results showed no association. A positive association between BMI and sedentary time was also reported in the systematic literature review by O’Donoghue and colleagues,\textsuperscript{15} while Rhodes and colleagues concluded that the relationship did not appear strong.\textsuperscript{14} As all of these studies were cross-sectional, the causal relationship between weight status and sedentary time is unknown. In other words, it is unclear whether people are overweight because they sit more, or whether they are more sedentary because they are overweight. Systematic literature reviews found insufficient or mixed evidence for longitudinal associations between sedentary time and weight status.\textsuperscript{17,18}
The association with physical activity was studied in all studies except the accelerometer pooling study. In the Eurobarometer survey as well as the HELIUS study, physical activity was strongly and inversely associated with sedentary time. The Eurobarometer survey showed a ‘dose-response’ relationship, with decreasing odds ratios of sitting time with each increase in activity quartile. In the HELIUS study, meeting the physical activity recommendations was identified as an inverse correlate of sedentary time across all ethnic groups. Compared to respondents accumulating 30-149 minutes of moderate to vigorous physical activity per week, the Australian Health Surveys showed statistically significant higher odds ratios of sitting ≥7 hours per day for respondents accumulating <30 minutes of physical activity per week, but no difference with those accumulating ≥150 minutes per week. Rhodes and colleagues also reported an inverse relationship between leisure-time physical activity and especially TV viewing while O’Donoghue and colleagues reported inverse associations between physical activity levels and sedentary time. At first sight, this association might seem contributable to the mere effect of time replacement; that time not spent on sedentary behaviour was automatically spent actively. This is, however, not the case. Sedentary time (<1.5 METs) and physical activity (>3.0 METs) were not the inverse of each other in these studies, as light physical activity (1.5-2.9 METs) was not taken into account. In addition, in the HELIUS study, approximately 20 minutes of moderate to vigorous physical activity per day was associated with 120-200 minutes less sedentary time.

The association between marital status and sitting time was assessed in the Eurobarometer survey and the Australian Health Surveys. In the Eurobarometer survey, married people were shown to sit less in the univariate, but not the multivariate models. In the Australian Health Surveys, the (adjusted) logistic regression analyses showed lower statistically significant odds ratios of married people. In their reviews, both Rhodes and O’Donoghue reported mixed results between marital status and TV viewing and total sitting time. Marital status might be a proxy for having children, which was included in the Eurobarometer models but not in the Australian Health Surveys and might thus explain the difference.

Five of the six common correlates of sedentary time identified in the studies in this thesis (gender, age, socio-economic status, weight status and physical activity) are individual-level factors within socio-ecological models. They do not cover the whole width of this individual domain, as psychological correlates, such as self-efficacy, are lacking. In addition, one social correlate was included in two of the studies: marital status. Some (physical) environmental (e.g. living in a rural or urban area) potential correlates were included in the Eurobarometer survey, but in none of the other studies. This indicates that the current evidence-base for correlates of sedentary time is still limited, especially for psychological and non-individual level correlates. This
was also one of the conclusions of the systematic literature review of O’Donoghue and colleagues,\textsuperscript{15} indicating that the findings of this thesis reflect the current state of the field.

In addition, Chastin and colleagues recently published the Systems Of Sedentary behaviours (SOS) framework, identifying six clusters of determinants of sedentary behaviour.\textsuperscript{19} Through expert consensus, the cluster ‘Institutional and Home Settings’ (i.e. “all factors influencing the physical and human organisation of institutions individuals/groups live in or interact with”) was regarded to have the highest research priority. Socio-economic status is one of the correlates belonging to this cluster, and this was consistently included in the studies in this thesis. In addition, the Eurobarometer survey included a few additional potential correlates regarding the Institutional and Home Setting, such as television/computer ownership and internet use frequency. However, the general scarcity of data on these potential correlates demonstrates the need for studies focused on this particular cluster of determinants.

**Correlates of physical activity**

Across the studies included in this thesis, correlates of physical activity were only assessed in the accelerometer pooling study (chapter 5). In this study, women, older people, obese people and lower educated people were more likely to be physically inactive i.e. not meet the physical activity recommendations. These correlates were all in line with previous research.\textsuperscript{20} The fact that women are less sedentary but also less active can be explained by the observation that women spent more time in light physical activities. The lower physical activity levels of older adults probably reflect a (perceived) decreased ability to be physical active. However, the WHO does recommend older people to be as physically active as possible.\textsuperscript{5} As with sedentary time, the direction of the relationship between physical activity and obesity is not clear, as this was a cross-sectional study. People might be overweight because they are not physically active, or they might not be physically active because they are overweight. Finally, the association between education and physical activity might indicate a lack of motivation, ability and/or opportunity to be physically active in lower educated people.

In view of the socio-ecological model, all correlates identified in this study are individual-level factors. However, correlates at the social or environmental levels have been investigated in other studies. A systematic literature review by Trost and colleagues, for example, provided an extensive overview of the current evidence base for biological, demographic, psychological, cognitive, emotional, behavioural, social, cultural, physical environment and physical activity characteristics-related correlates of physical activity in adults, identifying correlates such as expected benefits, activity history, social support, climate/season and perceived effort.\textsuperscript{20}
Correlates of being sedentary and inactive

Correlates of the combination of being sedentary and inactive were assessed in the accelerometer pooling study (chapter 5) and the Australian Health Surveys (chapter 6). In the accelerometer pooling study, men, people aged 67-75 years, and obese people were more likely to be classified as being sedentary and inactive. In the Australian Health Surveys, men, people aged ≥75 years and obese people were also more often sedentary and inactive. In addition, low self-rated health was also strongly associated with being classified as sedentary and inactive. As stated before, few studies have focused on this combination of high levels of sedentary behaviour and physical inactivity, and the existing studies all used different classifications. Therefore, it is difficult to compare results. However, these two studies provide a first indication that men, older people, and people with suboptimal health might be at higher risk for this detrimental combination of behaviours.

Conclusions regarding correlates of sedentary behaviour and physical activity

According to the studies included in this thesis, men, obese people, people with a higher socio-economic status and physically inactive people seem to be more sedentary while women, older people, obese people and lower educated people seem to be more frequently physically inactive. In addition, men, older people, and people with suboptimal health were more often classified as sedentary and inactive. These findings provide an indication of which groups are more likely to be sedentary and/or inactive and should thus be targeted in public health interventions and policies. However, they do not provide many clues as to why these individuals are sedentary. Relatedly, the correlates studied in this thesis were mainly socio-demographic, individual-level correlates. This is not a reflection of the physical activity research field, where correlates belonging to other levels have been studied before. However, for sedentary behaviour the evidence base does seem to be limited to individual-level correlates. This is problematic, as a broader perspective is needed to fully understand when, how and why people engage in sedentary behaviours. Simply transferring the known contextual correlates of physical activity to sedentary behaviour is not suitable, as sedentary behaviours are likely influenced by other contextual factors. For example, whereas the outdoor environment is known to be an important factor for physical activity, sedentary behaviours are likely more influenced by indoor environmental factors.

Methodological issues

The studies in this thesis were carried out with great care. Nevertheless, they all had their strengths as well as their limitations that need to be acknowledged. These methodological issues are discussed below, distinguishing between the systematic literature reviews (chapters 2 and 3) and the secondary data analyses (chapters 4-7).
Systematic literature reviews

The two systematic literature reviews included in this thesis were part of a set of four reviews. The search, article selection, data extraction and quality assessment were conducted conjointly across the four reviews. The strengths and limitations of these reviews are discussed below.

The main strength of the systematic literature reviews lies in the thoroughness of the process. First of all, review protocols were written based on the “Centre for Reviews and Dissemination’s guidance for undertaking reviews in health care”, and registered in the PROSPERO international prospective register of systematic reviews. These protocols were adhered to throughout the review process. Combining the search was not only more efficient, it also decreased the risk of missing articles. For example, articles that focused on physical activity but also included sedentary time could have been missed by separate searches, but not in the combined search. In addition, the search covered six literature databases, including one database focused on grey literature, and several additional search strategies (i.e. forward tracking, backward tracking, searching authors’ literature databases). Moreover, all articles were reviewed, extracted and assessed by two independent researchers, decreasing the chance of errors.

Despite the thorough review process, the possibility remains that appropriate articles were not identified. On a related note, since only articles published in the English language were included, articles in other languages could have been overlooked. However, due to their international character, it is most likely that cross-European studies would have been published in English.

All four systematic literature reviews focused on studies that were conducted in at least two European countries. The rationale behind this decision was based on a 2010 report, in which the WHO Regional Office for Europe identified all national surveillance systems within Europe and concluded that their results were not comparable due to differences in measurement methods. Therefore, the systematic literature reviews were focused on international studies that would provide the opportunity for cross-country comparison, at least within studies. This means that national studies were excluded from the reviews, even if objective data -which might have been better comparable- were collected. It should be noted however, that study differences in data collection and processing still would have limited the comparability of this objective data.

Several articles included in the reviews reported on the same study. To avoid presenting results from the same data multiple times, one article was selected per study. This choice was based on the information presented in the article and their similarities with the other articles. These selection criteria were somewhat arbitrary. However, since the articles were all based on the same data, it is unlikely that other choices would have resulted in different conclusions.
Finally, systematic literature reviews are commonly influenced by publication bias. However, as the current reviews did not present associations or effects, but focused on prevalence numbers, it is not likely publication bias influenced the results of the reviews.

**Secondary data analyses**

The four remaining studies in this thesis were secondary data analyses of existing data; using data that was already collected for other purposes. Secondary data analyses have several advantages, including the efficiency of using existing data rather than collecting new data. Pooling multiple existing datasets has the added advantage of increasing the number of participants and thus the statistical power, allowing more statistically enhanced as well as subgroup analyses. However, these secondary data analyses also have some methodological issues, which are discussed below.

The first issue relates to the availability of appropriate data. One of the consequences of conducting secondary data analyses is the dependency on the available data. If the data do not exist, it is not possible to analyse them. In the current research, availability of data was especially an issue for sedentary behaviour. As the systematic literature review on adult population levels of sedentary behaviour showed, cross-European data on the population levels of sedentary time in European adults are scarce, with the Eurobarometer surveys being the only source of comparable data across a large number of European countries. In the related systematic literature review on population levels of sedentary time in European children and adolescents, the number of existing studies was shown to be larger, but they included a large variety of assessment methods and tended to study screen time instead of total sedentary time. With regard to the correlates, a recent position paper by Chastin and colleagues discussed the available data on determinants of sedentary behaviour, and concluded they are “either inexistent, inaccessible, or not usable for cross-European research”. This limited availability of meaningful cross-European data on prevalence and correlates of sedentary time limited the possibilities of secondary data analyses.

Obtaining the data is a second possible issue. In 2016, Wilkinson and colleagues published the “FAIR” principles for scientific data management and stewardship. These principles state that data should be Findable, Accessible, Interoperable, and Reusable (FAIR). Even though some of the data was difficult to obtain due to strict data sharing policies, in the end all data requested for the research in this thesis was obtained. The Eurobarometer survey data was publicly available through the GESIS – Leibniz Institute for the Social Science, the accelerometer pooling data as well as the HELIUS data were shared by the data owners under the conditions of a data
A third issue regards the representativeness of the study population, which relates to the degree to which the results found in the study population can be generalised to the population as a whole. If the participants selected or included in the study do not represent the target population there is selection bias, limiting the generalisability of the results. This is especially important for prevalence studies aiming to reflect population levels. While the true characteristics of the whole population are unknown, the response rate and the distribution of basic socio-demographic characteristics such as gender and age can provide an indication of the representativeness of the study population. In the Eurobarometer survey, for example, the study population might not have been representative for the whole population, based on the low response rate (46 percent) and the high average age (52 years) of the study sample. This means that the reported levels of sedentary behaviour might not reflect true population levels. In addition, in the accelerometer pooling study, differences in samples across the different studies might have potentially hampered the comparability of the studies. This was most apparent when comparing the two Swedish studies, one population-based study and one cohort study, who reported largely different population levels. This illustrates the importance of appropriate, population-based study samples. In the HELIUS study, more active and less sedentary people might have been more willing to wear the Actiheart monitor, resulting in more homogeneous ethnic groups in the study than in real life, possibly concealing differences in sedentary time between the ethnic groups. One possible solution for selection bias is weighing the data for known characteristics of the population, such as gender and age, as was done in the Australian Health Surveys. However, as true population levels of sedentary behaviour and/or physical activity are unknown, it is not possible to weigh the data for this. In an attempt to take selection bias into account, all statistical analyses in this thesis were adjusted for gender, age and other possible confounding factors. In addition, generalisations of the study results to other populations were made with caution.

How the data was collected, i.e. how sedentary behaviour, physical activity and their correlates are measured, is a fourth issue, as this determines their validity and thus the results and conclusions they bring forward. The majority of the studies identified in the systematic literature reviews, as well as two of the secondary data analysis studies in this thesis, used subjective, self-report measures to assess sedentary behaviour, physical activity and the potential correlates. While self-report measures provide the opportunity to assess the behavioural context, they are prone to social desirability and recall bias, which usually leads to under-reporting of sedentary time and over-reporting of physical activity levels. In addition, linguistic and cultural differences in interpretation and reporting might complicate comparisons across countries and
cultures, limiting their use in an international context. Moreover, as the Australian Health Surveys only assessed occupational and leisure-time sitting, ignoring domains such as transport, household and education, and only assessed occupational sitting in full-time employees, underestimation is even more likely. In the accelerometer pooling study and the HELIUS study, some of these issues were overcome by the use of an objective monitor. Even though this likely resulted in more valid estimates of physical activity and sedentary time levels, some issues remained. In the accelerometer pooling study, for example, cross-study differences in population sampling and data collection still limited comparability across studies. And the ‘subjective’ method to visually identify sleep time in the 24-hours data potentially compromised the objective nature of the HELIUS data. Moreover, these studies still used self-reported questionnaires to assess the potential correlates, that might suffer from the same biases and comparability issues that were mentioned above.

The fifth and final issue concerns data handling and statistical analyses. All analyses were carried out according to pre-defined analyses plans, advised by statistical experts. However, each of the studies included in this thesis have some remaining issues. In the Eurobarometer survey, for example, respondents were asked to choose between several categorical response options to report their sitting time. The interval was 60 minutes (e.g. 1.5 hours-2.5 hours), which prevented an accurate representation of sedentary time. However, this was solved by dichotomising sitting time into sitting ≤7.5 hours per day and >7.5 hours per day, based on a recent meta-analysis.10

The most evident issue with the accelerometer pooling study was the harmonisation of the potential correlates. Even though all five studies included a whole range of potential correlates, only four variables (gender, age, weight status, educational level) were included in all studies and could thus be harmonised. This demonstrates the balance in secondary data analyses between the gain of studies and the loss of variables. Finally, in the HELIUS study, the sample size and related statistical power were an issue in the stratified analyses to explore correlates of sedentary time in ethnic groups. As some of these groups only included a small number of participants (e.g. 73 Moroccan participants) it is uncertain whether potential correlates were not associated with sitting time, or whether their association could not be demonstrated.

**Implications and recommendations for research**

The aim of this thesis was to assess existing data to study the prevalence and correlates of sedentary behaviour and physical activity in European adults.

With regards to the prevalence of sedentary behaviour, the systematic literature review showed that the Eurobarometer surveys are currently the only source of comparable sedentary behaviour data across a large number of European countries. This is worrisome, as these surveys
are not conducted for public health purposes, irregularly include sedentary behaviour, and do so using a single-item self-report question (with a response scale that changed between surveys, hampering comparisons over time). For physical activity, the difficulties in determining current population levels were mainly caused by the large variety in assessment methods and reported outcomes in the existing studies, as well as the lack of studies using objective measures to assess physical activity. These issues demonstrate the need for standardisation and/or harmonisation of measurement methods of sedentary behaviour and physical activity in cross-European studies.

Harmonisation of existing data could be accomplished by sharing, pooling and reanalysing questionnaire and/or accelerometer data, as was done in the accelerometer pooling study in this thesis and is continuously done the International Children’s Accelerometry Database (ICAD). In 2016, Wijndaele and colleagues published an overview of the available accelerometer data in adults to date, identifying 76 studies from 36 countries. However, the accelerometer pooling study demonstrated the added value, but also the limitations of such retrospective harmonisation. More specifically, the remaining differences in sampling strategies and data collection across the different studies, the small amount of variables that were included in all studies and could thus be harmonised, and the limited number of countries with national population-based studies all hampered true comparisons across studies and countries.

Therefore, standardisation of cross-European studies is recommended. This process can be guided by recent initiatives such as the ‘Diet and Physical Activity measurement toolkit’ of the UK Medical Research Council that provides an overview of the available measurement methods for sedentary behaviour and physical activity, and the recently published reporting guidelines for accelerometer research. Such initiatives can help the research community to come closer to consensus on valid and reliable measurement methods to be used. Standardised measurement methods can be integrated in existing studies or surveillance systems, or a new cross-European surveillance system of sedentary behaviour and physical activity could be installed.

In order to be truly informative, studies should aim to use a combination of objective measures such as accelerometers and inclinometers to provide valid and comparable estimates of the population levels of sedentary behaviour and physical activity, and subjective measures such as questionnaires and diaries to assess the behavioural context that can be used to inform interventions and policies. In addition, longitudinal studies are needed to monitor changes in population levels over time, preferably in population representative samples.

While the correlates of physical activity are reasonably well-described, this is not true for sedentary behaviour. Most studies included in this thesis, as well as the studies included in the
General discussion

systematic literature review by O’Donoghue and colleagues, only included the ‘usual suspect’ individual-level correlates of sedentary behaviour, such as gender, age and BMI. These variables provide insight into who were sedentary, but not necessarily on why they were sedentary. Therefore, future studies should focus on a wide range of potential correlates of sedentary behaviour, inspired by models such as the socio-ecological model\textsuperscript{12} and the Systems of Sedentary behaviour (SOS) framework.\textsuperscript{19} Qualitative research in addition to quantitative research potentially increases the insight into this behaviour and its correlates. In addition, longitudinal studies provide the opportunity to study causality, aiming to identify determinants and predictors of sedentary behaviour, as opposed to just the associated correlates.

In summary, there is a need for longitudinal cross-European surveillance of the population levels of sedentary behaviour and physical activity, as well as their correlates or determinants, preferably in population representative samples. These studies should use a combination of objective and subjective standardised measurement methods to assess population levels of sedentary behaviour and physical activity, and quantitative as well as qualitative methods to assess a wide range of potential determinants, inspired by theoretical models and frameworks.

Implications and recommendations for practice

Despite their differences, all studies in this thesis reported high levels of sedentary behaviour and physical inactivity in European adults. According to harmonised accelerometer data, 20 percent of European adults might be highly sedentary, 70 percent might not meet the physical activity recommendations of 150 minutes of moderate to vigorous physical activity per week, and around 10 percent might be defined as sedentary and inactive. As these behaviours are related to several non-communicable diseases and increased risk of (all-cause) mortality, this demonstrates the importance to develop, implement and evaluate interventions and policies aiming to increase physical activity and decrease sedentary behaviour. In general, adults should be encouraged to participate in at least 150 minutes of moderate to vigorous physical activity per week, as is currently recommended by the WHO.\textsuperscript{5} In the absence of comparable guidelines for sedentary behaviour, adults can be recommended to reduce and break up their sedentary time, an advise that is currently included in the United Kingdom and Australian physical activity guidelines.\textsuperscript{39,40}

Even though more research on the correlates of especially sedentary behaviour is needed, the research in this thesis does provide entry points for targeted interventions and policies. First of all, in view of the novelty of the evidence and the high related health-risks, specific attention should be given to the combination of high levels of sedentary behaviour and low levels of physical activity. As obese people are consistently identified as a risk group for high sedentary levels, physical inactivity, and the combination of the two behaviours, they deserve special
attention in public health interventions and policies. In addition, as the associations with gender and socio-economic status are dependent on the behaviour, public health strategies should differentiate. Women and people with a low socio-economic status should be targeted to become more physically active, while men and people with a higher socio-economic status should be targeted to become less sedentary.

Focusing on sedentary behaviour, a recent systematic literature review by Martin and colleagues assessed the potential of interventions to reduce sedentary time.\textsuperscript{41} They concluded that interventions based on lifestyle or sedentary behaviour were indeed able to reduce sedentary time by 24-42 minutes per day, but found no effect for physical activity interventions or combined physical activity and sedentary behaviour interventions. This might indicate a need for sedentary behaviour-specific interventions. In response to the strong association between occupation and sitting time, an increasing amount of interventions have been developed in the last years aiming to decrease occupational sitting. Recent systematic literature reviews concluded that environmental changes such as providing sit-stand desks might be able to decrease occupational sitting time, although larger and longer studies are needed.\textsuperscript{42,43} Studies have shown beneficial health effects of breaking up prolonged sitting time\textsuperscript{44} and of time spent standing.\textsuperscript{45,46} However, these associations might be dependent on habitual physical activity. In addition, prolonged (occupational) standing also carries potential health risks of its own, such as varicose veins and lower back pain.\textsuperscript{47} This suggests that the solution to reducing sedentary behaviour needs to be sought in finding a healthier daily balance between sitting, standing and (light, moderate and vigorous intensity) physical activities.

**Conclusions**

This thesis aimed to use existing data to study the prevalence and correlates of sedentary behaviour and physical activity in European adults. Actual population levels of sedentary behaviour and physical inactivity are currently unknown, but the high estimates demonstrate the need for interventions and policies aiming to increase physical activity and decrease sedentary behaviour. People with obesity show high levels of physical inactivity, sedentary behaviour and the combination of the two behaviours and thus deserve special attention. In addition, men and higher educated people should be encouraged to be less sedentary while women and lower educated people should be encouraged to be more active. There is a need for longitudinal surveillance of physical activity and sedentary behaviour and their determinants, using a combination of objective and subjective measurement methods and quantitative as well as qualitative study designs. Understanding why people are inactive and/or sedentary is the first step towards a more active, less sedentary and consequently healthier population.
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