# *Chapter 10*

# Physical inactivity

Fiona C. Bull, Timothy P. Armstrong, Tracy Dixon, Sandra Ham, Andrea Neiman and Michael Pratt

## Summary

Physical inactivity is recognized as an important risk factor for multiple causes of death and chronic morbidity and disability.

Physical activity was chosen rather than physical fitness as the measure of exposure because it is through increases in the behaviour (physical activity) that health benefits accrue and improvements in cardiorespiratory fitness can be achieved. Moreover, there were insufficient data available worldwide to consider fitness as the exposure. Exposure was assessed as a trichotomous variable to avoid limiting the assessment of total burden to only that associated with the highest risk, namely the most inactive (a dichotomous approach). However due to a lack of data on physical inactivity, use of a more detailed (continuous) exposure variable was not possible nor was the use of a fourth category of "high activity". Therefore, our estimates of burden are likely to underestimate the total attributable burden to inactivity because of limitations with measures of exposure. Level 1 exposure (inactive) was defined as "doing no or very little physical activity at work, at home, for transport or in discretionary time". Level 2 exposure (insufficiently active) was defined as "doing some physical activity but less than 150 minutes of moderate-intensity physical activity or 60 minutes of vigorous-intensity physical activity a week accumulated across work, home, transport or discretionary domains".

We found a wide range of survey instruments and methodologies have been used for collecting, analysing and reporting data on physical activity. Most data were available for discretionary-time activity, some data were found on occupational activity and little and no national data were available for transport- and domestic-related activity, respectively. A comprehensive literature search and contact with key agencies and known researchers uncovered over 50 data sets on physical inactivity in adult populations covering 43 countries across 13 subregions.[1] However,

only 21 data sets covering 32 countries met our inclusion criteria. Hierarchical modelling techniques were used to predict discretionary-time activity using age, sex, geographic region and a measure of tertiary education. Linear regression was used to predict occupational activity and transport-related activity using two World Bank indicators (% employed in agriculture and car ownership, respectively). We used these estimates to compute the level of total inactivity for 145 countries and aggregated these data to create estimates for 14 subregions.

The final global estimate for total inactivity (level 1 exposure) was 17.1% and this ranged from 10.3% in AFR-D to 24.8% in EUR-C. Across most but not all subregions females were slightly more inactive than males and younger adults were less inactive than older adults (range 9.6–46.8% across the 12 age-sex categories). The final global estimate for insufficient activity (level 2 exposure) was 40.6% and this ranged from 31.7% in AMR-D to 51.5% in WPR-A.

The independent causal relationship between physical inactivity and ischaemic heart disease, ischaemic stroke, type II diabetes, colon cancer and breast cancer is well established; we provided new estimates of the magnitude of risk associated with inactivity. A comprehensive search of literature from 1980 onwards identified well over 100 studies assessing the relationship between physical inactivity and the set of health outcomes that met our criteria. Also, several quantitative and qualitative reviews of the association between physical inactivity and ischaemic heart disease and stoke were found but there were no quantitative meta-analyses for breast cancer, colon cancer and type II diabetes. Most of the epidemiological studies meeting our inclusion criteria measured discretionary-time activity, some studies assessed occupational activity but only a few studies incorporated transport-related activity. No study included domestic-related physical activity. Given these data and differences between previous work and our definition of exposure, we completed a series of new meta-analyses for each health outcome. To address concerns regarding measurement error associated with physical activity, an adjustment factor was incorporated into the meta-analyses. All risk estimates were attenuated for ages 70 and over. There is emerging consensus on the protective effects of activity in regards to preventing falls, osteoarthritis and osteoporosis and impaired mental health but these disease end-points did not meet our inclusion criteria.

Globally physical inactivity accounted for 21.5% of ischaemic heart disease, 11% of ischaemic stroke, 14% of diabetes, 16% of colon cancer and 10% of breast cancer. The results show small differences between males and females, due in part to differences in level of exposure and to different distribution of events between men and women. In summary, physically inactive lifestyles accounted for 3.3% of deaths and 19 million disability-adjusted life years (DALYs) worldwide. There were small, non-significant differences in the attributable fractions across subregions. Due to our conservative methods and a number of important limitations, our global estimates are likely to be an underestimate of the true burden attributable to inactive lifestyles.

## 1. Introduction

Physical inactivity is associated with many of the leading causes of death, chronic morbidity and disability. The apparent protective effect of being more active, and consequently less inactive, was identified first through studies of occupational activity over 50 years ago. Subsequent research has investigated different types, duration, frequency and intensity of activity in association with various cardiovascular, musculoskeletal and mental health outcomes. Today, there is a significant amount of literature quantifying and qualifying the role of physical inactivity as a risk factor and worldwide interest and efforts to increase levels of participation.

### 1.1 Choice of the exposure variable—physical activity or physical fitness

There is substantial epidemiological evidence for the protective effects of both a physically active lifestyle and of various levels of physical fitness. Yet, to date, it is still not possible to determine whether one of these exposure variables is more important than the other (Blair et al. 2001). Thus, in theory, either variable could have been selected as the measure of exposure for this project. The final selection of physical activity over physical fitness was based on several reasons. Firstly, physical fitness is primarily determined by patterns of physical activity, particularly activity undertaken in recent weeks or months (Blair et al. 2001). Secondly, there is a genetic contribution to physical fitness and while of some importance, genetic makeup is likely to account for less variation than the lifestyle behaviour (Bouchard 2001). Thirdly, assessment of physical fitness in large samples of adult populations is rare across the majority of countries and infrequent in those countries in which it has been undertaken. Moreover, studies of fitness often exclude adults with certain chronic conditions. Fourthly, most national and international recommendations specify public health targets in terms of reaching thresholds of physical activity not levels of physical fitness.

It is acknowledged that one advantage of choosing physical fitness as the exposure variable would be the opportunity to use an objective, physical measure such as maximum oxygen uptake. This would be desirable for several reasons, including correspondence with many epidemiological studies assessing relative risk. Disadvantages to this approach, however, stem from the lack of nationally representative population-based estimates, which outweigh the benefits. The difficulties associated with measuring behavioural risk factors are well known and the specific challenges pertaining to measuring physical inactivity are discussed in detail in the following sections.

Therefore, considering the scientific support, the availability of data, and consistency with public health initiatives, physical activity was selected in preference to physical fitness as the measure of exposure. Given that protective benefits come from undertaking physical activity, from here on, the risk factor is specified as *physical inactivity*. It is, however, impossible to limit the discussion of both conceptual issues and the reporting of data to solely the "absence" of physical activity. Therefore the reader is forewarned that both physical activity and physical inactivity are discussed. In places the term "physical (in)activity" is used to refer to either activity or inactivity.

### 1.2 Conceptual framework and definition of physical activity

The definition of the exposure of physical inactivity was determined after consideration of a number of factors. These issues included: what types of activity across what domains would be included/excluded; what cut-points between inactive and active would provide the greatest availability of data and opportunity for comparability across data sets and countries; and what cut-points would be consistent with established and emerging scientific evidence. Currently these issues are under considerable debate within the scientific community and there are no definitive answers. Thus, it is in advance of any consensus that a framework and workable definition of physical inactivity as an exposure is presented.

Traditionally, physical activity research has been interested in exercise defined as "planned, structured and repetitive bodily movement done to improve or maintain one or more components of physical fitness"(Caspersen and Stephens 1994). This interest focused attention towards certain types of exercise, mostly vigorous-intensity activities that were undertaken usually outside of work in recreational or discretionary time. In general terms it was acknowledged that some occupational or work-related activities could reach the threshold of vigorous-intensity and thus could potentially qualify as exercise and be beneficial to health. However, because technology and industrial development were causing a rapid decline in these occupations, particularly in developed countries, considerably less interest was invested in this direction. Moreover the opportunity to intervene was more promising outside the workplace. In essence, for those interested, particularly in developed countries, the focus was on exercise and the domain of "leisure-time". Many of the measurement instruments used today reflect this perspective.

A shift away from solely focusing on exercise started after the results from several large prospective cohort studies were published in the late 1980s and early 1990s. These studies were significant because they identified the protective effects of less intense physical activity (Blair and Jackson 2001; Blair et al. 1989, 1992, 2001). By 1996 these findings were endorsed by several leading institutions and scientific organizations (Pate et al. 1995) and formed the primary focus of the U.S. Surgeon General's Report on Physical Activity and Health (U.S. Department of Health and Human Services 1996). Combined, the evidence and the widespread endorsement shifted the paradigm towards the benefits of moderate-intensity activity such that efforts more recently have been directed towards increasing the amount of moderate-intensity activity undertaken by all adults and children. Such activities include brisk walking (>3 mph), recreational cycling and swimming.

Some have viewed this shift as premature and raised concerns about the detrimental impact on the promotion of the known additional benefits that come from enhanced physical fitness. Furthermore, the exact nature and possible differences between the dose–response relationship between physical fitness and physical activity with various disease outcomes is still under intense debate (Bouchard 2001; Kesaniemi et al. 2001; Macera and Powell 2001). Meanwhile, the shift in focus has raised questions on the definition of "moderate-intensity", on what activities constituent moderate-intensity and on how to measure the prevalence of this broader range of activities within populations. Critically, it opened up the debate on whether activities undertaken in domains of life other than leisure-time can or should be considered beneficial and thus "counted".

The answers to these important questions are often population-specific because different types of physical activities are undertaken between and within communities that differ across social, economic, geographical and religious aspects of life. Moreover, the importance of, or necessity for, physical activity in different domains of life differs between cultures. It is these differences and the complexity of measuring physical activity that have hindered the development of any international consensus on definitions and common instruments for assessing physical inactivity. Growing concern over these issues has led to several recent initiatives and considerable progress has been made toward developing a common measurement instrument for use in the future. The International Physical Activity Questionnaire (IPAQ) is a new instrument assessing total physical activity and sedentary behaviour (time spent sitting) developed by a group of international experts and tested in collaboration with researchers from 12 countries across six continents. IPAQ has demonstrated good–very good reliability and moderate criterion validity (Craig et al. 2003). Further details are available at http://www.ipaq.ki.se.

For the purpose of this project, it was acknowledged that physical (in)activity can occur across four domains: work, domestic, transport and discretionary time (see Figure 10.1). Each domain represents a sphere of daily life that is common to most populations regardless of culture or economic development and within each domain it is possible to be more or less active. The opportunity for, and the level of, physical (in)activity in each domain for any national population is dependent on

**Figure 10.1** Generic framework for four domains of physical (in)activity

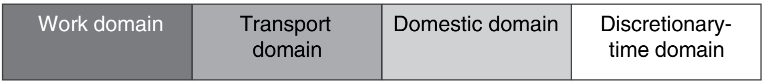



**Figure 10.2** Relative importance of domains of physical (in)activity in two hypothetical countries

Country A

In country A, the work, domestic and transport domains contribute very little opportunity to be active. For example, this country may have well-established and complete coverage of water and electricity supply to homes and dwellings thus reducing the demands to be physically active in the domestic domain. Extensive car ownership with poor public transportation systems may have reduced the opportunity and need for activity in the transport domain. Work may have become more sedentary due to technological innovation. Thus the discretionary (leisure) domain represents the predominate domain where the greatest opportunity to be active exists. This may be typical of a developed country.

Country B

In country B, the work, domestic and transport domains contribute the most opportunity or most necessity to be active. For example, this may represent a country that has a high proportion of the adult population employed in agriculture or heavy industry both of which may require large amounts of vigorous physical exertion. Domestic activities may still involve carrying water and/or other food preparation techniques that require moderate- or vigorous-intensity physical activity. Transportation may be dominated by walking or cycling with minimal public transport alternatives and low car ownership. Relative to the previous domains, the discretionary domain may be much less important in terms of providing opportunity or need to be active for the population of this country. This may be typical of a developing country.

economic, technological, social, cultural and religious factors interacting at the individual, community and national level. Moreover, the relative importance of each domain, in terms of either representing an opportunity or necessity to be (in)active, will vary between and within countries over time. A generic model of this framework is shown in Figure 10.1 and two hypothetical countries (a and b) are shown in Figure 10.2, each with a brief description.

Using four domains as a framework for the definition of exposure is in contrast to many previous approaches to defining and measuring physical (in)activity, which made the task of searching for and interpreting global data on physical (in)activity more complex. National data on physical activity are not readily available in many parts of the world. There is even less data available across the four domains of work, domestic, transport and discretionary-time activity. Despite this limitation, the framework was selected because it presents the exposure variable in a way that has relevance to all countries around the globe. The framework can be applied both now and in the foreseeable future, when many countries and large numbers of people are expected to experience major transitions in economic, social and health terms (Chockalingam 2000; Reddy and Yusuf 1998). The underpinning assumptions of our framework include: that physical activity can take place in different domains; that some of this activity is of sufficient intensity and duration to provide protective effects from certain diseases; and that the pattern of physical activity in each domain is very likely to vary across countries. The measurement issues related to each domain are discussed below.

## 1.3 Measurement issues

### *Instruments*

There is currently no universal or even commonly used measure or instrument for physical (in)activity. This poses a serious limitation on efforts to compare levels of exposure across populations, a problem frequently cited in the literature and by others attempting international comparisons (Caspersen and Stephens 1994; IARC 2002).

Physical (in)activity is typically assessed using a series of questions as part of a self-administered or interviewer-administered questionnaire. The wording of the questions, the examples used (if any) and the response format can and do vary. A recent compendium of instruments illustrates the diversity of approaches, many of which are more suitable to the research environment rather than public health surveillance systems (Kriska and Caspersen 1997).

We undertook a review of instruments currently used to gather data at a national or large-scale population level and found that, in general, there are five different formats for questions assessing discretionary-time and work-related activities. These range from items asking for a yes/no response regarding participation in listed activities (format 1) to detailed responses about frequency, duration and type of activity performed (format 5). The formats for questions assessing physical (in)activity in these two domains are outlined in Table 10.1, and the limitations are briefly mentioned below. Few instruments were found that assessed transport-related and domestic activity.

### *Measures of discretionary-time activity*

Instruments vary in both their intention and ability to capture details on different aspects of discretionary-time physical activities, namely: the specific type of activity (e.g. swimming, tennis, gardening, cycling); frequency (how many times in a specified time frame); duration (usually in minutes); and intensity (e.g. light, moderate, vigorous). Moreover, they use a variety of referent time frames (e.g. last week, last month, usual week, past year).

Format 1 and format 2 (Table 10.1) are similar in assessing frequency and duration of specific types of activity (either prompted or

**Table 10.1** Summary of five formats of questions assessing physical (in)activity

| *Format* | *Question/response format* | *Example* |
|---|---|---|
| *Discretionary (leisure) time* | | |
| 1 | Question presents a list of sports/activities. Response options are usually Yes/No. If yes, then frequency and duration (minutes) are usually assessed. Reference time frame vary from one week to 12 months | Europe (Institute of European Food Studies 2001)<br>Brazil (Datafohla 1997)<br>New Zealand (Hillary Commission 1998)<br>Canada (C. Craig, unpublished data, 2001) |
| 2 | Question asks if any sports or activities have been undertaken but no lists are shown/provided. Selected examples may or may not have been provided. If yes, type, frequency and duration (minutes) are usually assessed. Intensity of activity may be recorded also | USA (CDC 1998) |
| 3 | A single question asking which of a set of descriptions "best describes" the respondents patterns of activity. Descriptions can cover multiple domains and/or include combinations of activities of different intensity. A variation is to present two or more questions in this format with each question specifying the domain (e.g. at work or outside of work). Responses to the latter can be combined to create a score of activity. Another variation is to present single or multiple statements about physical activity, in one or more domains, and the response scale captures frequency using a Likert scale (e.g. never through to very often), or categories or is open ended | Argentina (Instituto Gallup De La Argentina 2001)<br>Chile (Jadue et al. 1999)<br>Egypt (Herman et al. 1995)<br>Estonia, Latvia, Lithuania (Pomerleau et al. 2000) |
| 4 | All activities over a specific time frame are recorded (e.g. last 24 hours or last 7 days). Responses include duration (minutes) and can be recorded by intensity and/or by domain | Ethiopia (Alemu and Lindtjorn 1995) |
| 5 | A series of questions assess participation in categories of activities usually defined by intensity (e.g. moderate-intensity or vigorous intensity). Examples usually provided. Response is usually Yes/No and if yes, frequency and duration (minutes) recorded. Walking as a specific activity can be asked either as a separate question specifying which types of walking to include (all walking, not at work, for transport) or walking is given as an example within the category of moderate-intensity activity | Australia (Armstrong et al. 2000) |
| *Work-related* | | |
| 1 | Question asks respondents to indicate which description best describes their work "mostly" or "usually". Response categories are often: 1) primarily sitting/standing; 2) a lot of walking; 3) hard physical (sweat) labour | South Africa (Steyn et al. 1991) |

**Table 10.1** Summary of five formats of questions assessing physical (in)activity (*continued*)

| *Format* | *Question/response format* | *Example* |
|---|---|---|
| 2 | Question asks respondents to indicate how much time spent doing specific categories of activity (e.g. sitting/standing, walking, hard physical labour). Response scale may vary and can include either hours per day or proportion of time at work | Canada (C. Craig, unpublished data, 2001)<br>Europe (Institute of European Food Studies 2001) |
| 3 | Singular or multiple questions assess participation in categories of work activities defined by intensity (e.g. light or very light, moderate, heavy or very heavy). Examples of tasks or occupations may be provided for each category. Hours or portions of time may or may not be provided | China (North Carolina Population Center 2001b)<br>Estonia, Latvia, Lithuania (Pomerleau et al. 2000) |
| 4 | Questions assess frequency and sometimes duration of specific tasks undertaken within a reference time period (e.g. 2–12 months) are recorded. Respondents are prompted with a list of activities | Japan (Iwai et al. 2000) |
| 5 | Occupational activity is assessed by classification of type of employment (e.g. brick layer, nurse) or occupation (e.g. professional, blue collar) | Not used by any study included in this chapter |

unprompted). Format 5 assesses categories of activities defined by intensity; the number and type of examples provided can vary. Additional criteria on minimum duration may also be specified. The diary or day-by-day recall methods are grouped together as format 4. However, format 3 is the most distinct set of instruments focusing on the level of activity, rather than its type or purpose. As a group they represent instruments that present categories or descriptions and use various response options, such as: pick the best description, or a Likert scale assessing frequency or duration, or scales such as 1–3 times/week, 4–6 times/week, 1–2 times/month.

Within each of the five formats, questions can be structured to assess level of activity in the discretionary-time domain only or they can address multiple domains. The latter, of course, makes it difficult to compare results across instruments. In the former, respondents are usually instructed to limit the activities they consider. Exactly how each instrument partially or totally includes/excludes different activities can however vary, particularly in regard to the following activities: walking; gardening; domestic/yard tasks. In addition, the majority of instruments focus on assessing participation in endurance/aerobic activities, probably due to the extensive literature supporting the links to health. However, activities that build muscular strength and increase flexibility are also important and warrant further attention.

Currently there is insufficient evidence to classify any of the instruments as right or wrong, but they are clearly different and there is good evidence that different instruments will produce different estimates of particular behaviours (Pratt et al. 1999). Much research has been undertaken testing different measures of physical activity to assess their reliability and validity (Jacobs et al. 1993). The more frequently used instruments (such as the Minnesota Activity Questionnaire, Seven Day Activity Recall) have been tested for reliability and validity in more studies across diverse populations (Kriska and Caspersen 1997). However, the questions used to gather population health data are often not established instruments and often lack formal testing.

*MEASURES OF WORK-RELATED ACTIVITY*

In recent times work-related physical activity has received less attention than discretionary-time activity. Therefore, there are sparse data on patterns of activity at work and much speculation on the accuracy of recall of work activities, especially potential discrepancies between recall and actual intensity and duration of activity (Jacobs et al. 1993; Leenders et al. 2001). In particular, there is concern about the extent of over-reporting because individuals may over-estimate intensity and/or duration of work-based activities.

The most frequently used approach to assessment in this domain is to ask about three types of activities chosen because they are common in many occupations (formats 1, 2 and 3 in Table 10.1). More specific assessment of work activity can be obtained using a detailed recall (diary) or prompted recall with a list of activities (format 4). Historically, job occupation has been used as a proxy measure for work-related physical (in)activity (format 5) but as technology and work practice differs between countries and over time this is deemed to be the least favoured approach. To date, there is little evidence on the reliability and validity of most of these instruments or approaches.

*MEASURES OF TRANSPORT-RELATED AND DOMESTIC ACTIVITY*

Measurement of transport-related and domestic physical activities is the least well-developed area. There are few specific questions or instruments available and some activities in these domains are captured as part of questions aimed more at the discretionary or work-related domains. This confusion makes quantifying the prevalence of physical (in)activity in the transport and domestic domains very difficult.

Most of the available data on transport-related activity are from sources within the discipline of transportation. Usually these data are limited to trip origin and destination, distance, duration and mode (e.g. cycling, walking). How well they capture walking and cycling as part of multi-modal travel can vary. Also transportation surveys rarely capture the perceived intensity of the activity although a computed measure could be obtained if distance and duration were both assessed. Data on patterns of transport are most often presented as modal split with total number of trips as the denominator; other metrics include miles of travel. Data in these formats are not readily integrated or compared with data from population health surveys on physical activity. Moreover, it is usually only in research projects that data on transport-related activities and physical activities in other domains are collected on the same individuals.

Assessment of domestic activities as a distinct domain is uncommon. If these activities are considered at all, they are usually included as examples within the structure of other questions. For example, washing floors or vacuuming can be given as examples of moderately-intense activities. However, within the field of diet and nutrition some researchers very carefully assess energy intake and energy expenditure. But for these purposes they often assess total energy expenditure using doubly-labelled water ($H_2O_2$), direct observation or very detailed diary methods. There is currently no suitable, valid and reliable instrument for use in assessing activity in the domestic domain. It is, therefore, evident that further instrument development is needed to advance the assessment of physical (in)activity in both transport and domestic domains.

*Further issues related to measurement methodology*

In addition to the use of a variety of instruments, the method of data collection can vary. Self-report instruments continue to be the most widely used method for assessing physical activity in adults (Sallis and Saelens 2000), particularly in developed countries. In these countries widespread coverage of telecommunications has led to increased use of telephone-based surveillance systems (e.g. the Behavioral Risk Factor Surveillance System in the United States of America). In contrast, household surveys remain more common in other regions (e.g. Central and South America, Asia, Africa). There is no scientific evidence to support one methodology over the other in terms of accuracy of data on physical activity. But it is possible that each method may obtain different estimates of the behaviour. If the magnitude and direction of this difference were known for different populations it would be possible to include some statistical adjustment. However, in the absence of this information the inclusion of data collected using different interview methods will be a limitation to our estimates.

Patterns of physical activity are known to vary across different climatic seasons (Pratt et al. 1999). Ideally national estimates would be based on data collected across all seasons (a 12-month period) or data collection would be limited to a specified season. Cross-country and global comparisons could then be conducted either using only data collected in comparable seasons or only data collected over all seasons. Needless to say, with the overall dearth of data on physical (in)activity it was not possible to impose seasonality criteria within this project and this feature of the data will be another limitation to our final estimates.

### 1.4 Quantifying levels of exposure

Once data on physical (in)activity have been collected using any one of the approaches described above, the data can be treated as either a continuous or categorical variable. There are examples of both approaches with national data from around the world. Both approaches were considered for this project but due to the availability and comparability of data we chose to treat physical inactivity as a trichotomous categorical variable. A brief description of both approaches is provided below.

*Treating physical (in)activity as a continuous variable*

Minutes of activity can be presented as a continuous variable either as mean minutes per specified time frame (e.g. per week or per day) or it can be used to derive an estimate of energy expenditure expressed as metabolic cost (metabolic equivalent, MET) or kilocalories/kilojoules (kcal/kJ). One MET represents the metabolic rate of an individual at rest and is set as 3.5 ml $O_2$/kg per minute or approximately 1 kcal/kg per hour (Kriska and Caspersen 1997). With this approach, analysts use available lists of the energy requirements of specific activities (Ainsworth et al. 2000) or standard MET values for categories of activity. For example, the following MET values are frequently, but not consistently, applied to the following categories: vigorous-intensity activities = >6 METs; moderate-intensity activities = 3–6 METs (= 4.5); walking = 3 METs (Ainsworth et al. 2000). Energy requirements of a large number of tasks across all four domains are available (Ainsworth et al. 2000).

The continuous measures were not selected as the basis for the definition of the exposure, nor were data in these formats available for use in any other way for two reasons. Firstly, these estimates were derived from different instruments, and each analysis used different criteria to compute their estimates. Thus, large variability prohibited comparability despite the seemingly similar continuous measures of risk. Secondly, data obtained as mean minutes, mean kcals or mean MET minutes of activity could not be used to compute the distribution of exposure because the relationship between these values and the pattern of inactivity in a population is not known. In contrast, the relationship between mean body mass index (BMI) and the prevalence of obesity in populations has been explored.

*Treating physical (in)activity as a categorical variable*

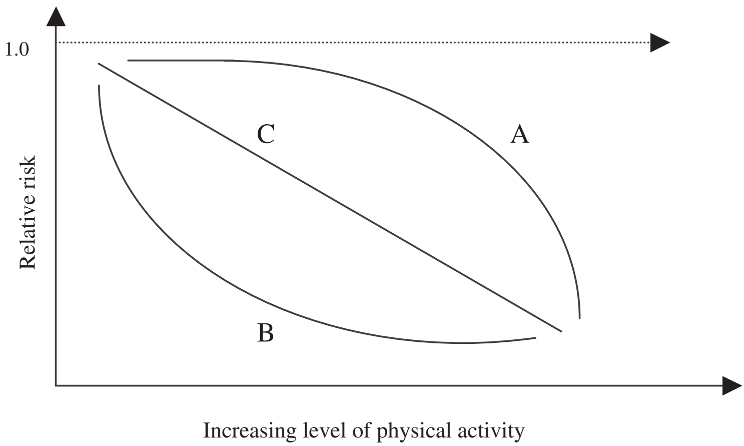
A current trend in analysing population data on physical (in)activity is to collapse the continuous data on minutes of activity into a categorical variable and report the prevalence estimates of each category. This is undertaken for each specific type of activity (e.g. walking, sports, lifting loads, climbing stairs) or more usually, the total amount of time spent doing physical activities assigned to different categories (e.g. total minutes of moderate-intensity or vigorous-intensity activity or heavy physical labour). The total of all activity can be calculated by summing all minutes of each activity or each category. However, close inspection reveals that these general approaches can include or exclude some specific physical activities or some domains depending on the investigators' purview. For example, gardening activities may be asked about but not included in calculations of activity (Armstrong et al. 2000) or work-related activity may be assessed but excluded or else reported separately from discretionary-time activity (Pomerleau et al. 2000). These specific analytic details necessitate very careful attention before comparisons between data sets can be attempted.

It has also become quite common among those dealing with national or regional surveillance data to present categorical data and to select the categories that correspond with various national public health guidelines or goals. A recent development has been the reporting of data as a measure of "recommended" or "sufficient" levels of activity in accordance with the U.S. Surgeon Generals' Report on Physical Activity and Health (U.S. Department of Health and Human Services 1996). This recommendation states that "30 minutes of moderate-intensity activity on most, if not all days of the week" is recommended for all adults. It is often, but not always interpreted and analysed as 150 minutes of moderate-intensity activity over at least five sessions or day/week. But there is still sufficient variation between the ways in which this recommendation is interpreted to make seemingly simple comparisons somewhat difficult.

### 1.5 Correspondence between measures of exposure used in population surveys and epidemiological research

The majority of epidemiological studies have explored the relationship between activity and disease outcomes by dividing level of activity into two or more groups. This is true whether the exposure was physical activity or physical fitness. The nature of the dose–response relationship has been explored using dichotomous categories (Morris et al. 1980), tertiles (Bijnen et al. 1998), quartiles (Folsom et al. 1985) and quintiles (Singh et al. 1998). Although continuous data are usually preferred because this maximizes the opportunity to detect associations, use of categorical data is warranted when the association may not be linear. Indeed, the nature of the curvilinear or linear relationship between physical activity and disease outcomes is a major focus of current research efforts (Blair et al. 2001; Kesaniemi et al. 2001; Williams 2001). Three possible relationships are illustrated in Figure 10.3. One contemporary view supports the presence of a threshold as shown by curve B in Figure 10.3, particularly for cardiovascular end-points. Curve B indicates that the greatest reduction in risk comes from increases at the lower levels of activity. Experts involved in a recent evidence-based symposium concluded that there is "an inverse and generally linear relationship for the rates of all-cause mortality, total cardiovascular disease, and

**Figure 10.3** A schema of three possible relationships between physical inactivity and disease end-points




coronary heart disease incidence and mortality and for the incidence of type 2 diabetes mellitus", a position reflected in curve C (Kesaniemi et al. 2001).

While the debate on the exact shape of the relationship is likely to continue, the use of categorical data may be justified given the known difficulties (i.e. error) associated with both the measurement instruments used to assess physical (in)activity and respondent recall of the behaviour. Under these circumstances continuous data may present an artificial level of accuracy and specificity.

It is worth noting one additional difficulty that obscures the level of correspondence between measures and thus the accurate application of relative risk results from epidemiological studies to prevalence estimates in order to calculate population attributable risk and the burden of disease. Namely, the lack of detailed descriptions of the absolute values of activity represented by the investigators' chosen categories. For instance, it is difficult to compare the level of activity in the lowest tertile of activity from study A with study B unless the activity level is defined and reported. Likewise it is almost impossible to make accurate interpretations of tertiles and quartiles without appropriate descriptive statistics for each group. This omission necessitates qualitative judgements when comparing or pooling results across studies and may obscure the strength and nature of the disease–risk factor association.

Notwithstanding, these are important limitations; currently the greatest concordance between measures of physical activity used in epidemiological studies and population surveillance is found at the lower and upper ends of the physical activity continuum. Application of the relative risk results for the least active group (be it tertile, quartile or quintile) to prevalence estimates for lowest level of activity in whole populations is possible. There is, however, less certainty surrounding the agreement between measures of low–mid levels and mid–upper levels of exposure.

Measurement error associated with assessing exposure to physical inactivity is a major limitation to this project. We addressed this problem in several ways. Our treatment of the exposure as a trichotomous variable avoids presenting a misleading level of accuracy. The definition of the categories corresponds with our greatest level of confidence in the accuracy of our data, particularly at the lower end. Our definitions and estimates of exposure within each domain accommodate the known or suspected direction of measurement error. Finally, as we describe in our review of epidemiology, our pooled meta-analyses included an adjustment for measurement error based on available evidence of reliability of the instruments used in each study.

## 1.6 Definition of exposure

In balancing the need for a conceptual framework with global relevance, concordance with the epidemiological evidence, current public health recommendations, as well as the limited availability of national data, the following definitions of a three level exposure of physical inactivity were developed:

*Exposed*

Level 1 Inactive:
defined as doing no or very little physical activity at work, at home, for transport or during discretionary time.

Level 2 Insufficiently active:
defined as doing some physical activity but less than 150 minutes of moderate-intensity physical activity or 60 minutes of vigorous-intensity physical activity a week accumulated across work, home, transport or discretionary domains.

*Unexposed*

Level 3 Sufficiently active:
defined as at least 150 minutes of moderate-intensity physical activity or 60 minutes of vigorous-intensity physical activity a week accumulated across work, home, transport or discretionary domains, which approximately corresponds to current recommendations in many countries.

In the work domain, inactive was defined as not doing any "hard" or "vigorous" physical activities at work. Where needed, we classified those that reported "mostly walking" or "mostly standing" or any equivalent category, as inactive. The effect of our definition is to potentially inflate the proportion classified as inactive at work because some adults may perform these tasks during their work in combinations of duration and intensity sufficient to gain some health benefits. However this is perhaps counterbalanced by at least some likely misclassification of adults as active due to "heavy" activity. In the absence of data with sufficient detail and no prior evidence on which to base our classification, our definition reflects the limitations of measurement in this domain.

Inactive in the transport domain was defined as no walking or cycling trips. Therefore, a single walk or cycle trip was sufficient for an adult to be classified as active in this domain. With few data on trips per person and no data on trip intensity or duration we accepted all walking and cycling trips as activity that could provide some health benefits. In contrast to the work domain this definition is lenient and the likely effect is to overestimate transport-related activity. However, unlike walking at work, which may be performed in short bouts and undertaken intermittently, transport-related activity may be of longer duration and undertaken at moderate-intensity. Inactive in the domestic domain was defined as no moderate- or vigorous-intensity domestic-related activity. However, with no national data worldwide we were unable to include this domain of activity in our assessment.

Insufficient activity was assessed by distinguishing between those adults who met the threshold of at least 150 minutes of moderate-intensity physical activity accumulated from one or more domains from those adults who did not. Given the lack of national data using the same or equivalent definition, we used the limited available data to develop an algorithm to estimate the prevalence of this level of exposure in each country. Full details of our methods for assessing inactive (level 1) and insufficiently active (level 2) are described in section 2.

### 1.7 Age groups included—adults but not children

Very few data were available on levels of (in)activity in children and adolescents. Moreover, the literature on children also includes a diversity of instruments and measurement methodologies (Sallis and Saelens 2000). Therefore, due to the magnitude of the task and the project timelines, the scope of this project was limited to quantifying exposure in the adult population only. Furthermore, there is limited epidemiological evidence demonstrating the level of current risk associated with inactivity and the selected health outcomes in populations aged <18 years.

### 1.8 Theoretical-minimum-risk exposure distribution

For physical inactivity the theoretical-minimum-risk exposure distribution could be set as equal to the estimated proportion of the total population that would be physically unable to meet the basic requirement of "at least some activity" in at least one domain. Data from Australia (2%) and the United States (4–6%) indicate that total disability (as defined by each country) is well below 10% of the population but it is unknown as to what proportion of this sub-population would be unable to do at least some physical activity.

Conceptually the theoretical-minimum-risk exposure is that level of activity which could *theoretically* occur if we could remove all individual, social and environmental causes of inactivity. Under such a scenario it is possible to consider a minimum that reflects all but the congenital causes of inactivity. As these are few, if any, and are likely to affect less that 1% of the whole population, we have chosen to set a theoretical minima as zero—a value that is comparable to other risk factors.

## 2. Estimating the prevalence of exposure

There were large gaps in the availability of nationally representative data on physical inactivity within some subregions and no data for several subregions. This was true across all four domains of activity included in the definition of exposure and both levels of exposure. To address this problem multivariate and linear regression analyses were conducted to create predicted values for missing data.

### 2.1 Search strategy

An extensive search was undertaken to identify studies reporting prevalence of inactivity for male and female adults (aged ≥15 years) worldwide. A particular effort was made to identify data in developing regions to avoid the need to derive estimates for these countries solely on data from developed countries.

Data were sought on physical inactivity across four domains, namely, discretionary time, work-related, transport-related and domestic. The initial search identified several studies in which population-based estimates of physical (in)activity were reported as a risk factor for specific diseases. Based upon these findings, a second search was conducted to include as keywords those diseases where physical inactivity has been shown to have a relationship, in both prevention and as a risk factor. For example, diabetes, cardiovascular disease, obesity and cancer were keywords used in the second search. Papers reporting data on physical inactivity in one or more domains were accepted for consideration. However, our search most frequently identified estimates for discretionary-time activity and rarely data on occupational, transportation or domestic (household) physical activity. Therefore separate searches for occupational and/or work, transportation and domestic domains were performed. For all searches, country names were included when global, international and/or world keywords were not used.

Publications reporting data collected between 1996 and 2000 were sought because the primary goal was to estimate prevalence of inactivity in the year 2000.

*Electronic literature search*

Medline, HealthStar and Chronic Disease Prevention searches were systematically conducted for studies published between 1996 and 2001 and limited to English (both United Kingdom and American English spellings) and Spanish languages. Additionally, multiple queries for each keyword were used. For example diabetes AND physical activity AND country X.

The following keywords were used:

- exercise, physical fitness, physical exercise, physical (in)activity, sedentary, energy expenditure;
- chronic disease prevention, diabetes, cancer, cardiovascular disease, hypertension, obesity;
- international, global, world, developing countries, country names;
- monograph, statistics, survey(s), prevalence;
- transportation (and physical activity/energy expenditure);
- occupation (and physical activity/energy expenditure and activity); and
- domestic (and physical activity/energy expenditure and activity).

*Electronic listserve*

A request for assistance in locating "gray" or fugitive literature (e.g. government and non-government agency reports) as well as unpublished data was posted on a cardiovascular listserve (procor-dialogue@healthnet.org).

*Government and non-government agencies*

World Health Organization (WHO) Headquarters, WHO Regional Offices, WHO collaborating centres and partner organizations worldwide were contacted to assist in identifying authors, researchers, organizations and institutions in obtaining national data on prevalence of physical activity, either at the country, regional or municipal level.

*Authors of relevant papers, relevant academic institutions and experts in the field*

Direct contacts were made with national governments, private and public institutions and individual authors to enquire whether unpublished or published data were available in English or other languages.

### 2.2 Criteria for considering sources and study inclusion

All identified studies were reviewed and included if they fulfilled the following criteria.

*Time frame*—data were obtained between 1996 and 2001. However, if there were no other data available for the country/region, studies reporting data collected after 1990 were considered.

*Sample*—studies reporting data from large, randomly selected, nationally representative samples with a wide age range were preferred. However, given this was not available in the majority of countries, studies with smaller samples, regional representative samples or narrow age ranges were considered.

*Measure of exposure*—the proportion of the population exposed (inactive) in one or more domains (discretionary time, occupational, domestic, transport-related) was required. In cases where data were presented as mean minutes, METs, total energy expenditure (kcals) or in any other way, the authors were contacted and asked to provide the data expressed as a proportion of the sample population. Where possible authors were asked to use our definition of exposure (overall inactivity) and/or the definition of inactivity relevant to each domain. If these data were obtained, they were considered for inclusion.

*Measurement instrument*—studies reported (or later provided) the instrument used to assess physical activity. As no standard measure of physical activity exists each instrument or set of questions was reviewed in this work. Those studies using previously published instruments assessing physical activity in one or more domain were accepted. Studies using questions unknown to the authors were assessed for face validity. A study was included only if it was deemed that the question(s) would provide reasonably comparable estimates.

*Data collection*—studies were included if data were collected by telephone survey, face-to face interview or during a physical examination.

### 2.3 Methods for selecting estimates where more than one data source existed

The following criteria were used to select data sources in cases where more than one source was available for a country or group of countries:

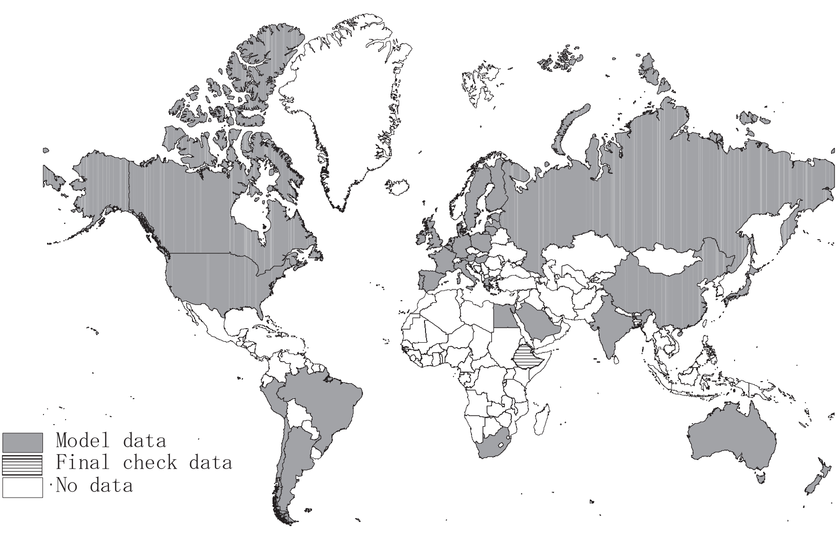
- the most recent data source—in some cases this meant the data were not yet in the public domain and specific analyses were undertaken for this project;
- nationally representative data or the study that allowed the best approximation of a national sample considering the studies representativeness and coverage of the desirable age range;

- a single study with common methods and representative population data from many countries was preferred over equal quality studies from individual countries; and
- the study providing the most comparable measure of physical inactivity as defined in this study.

## 2.4 Description of studies, including methodological qualities

Overall our search identified over 50 studies containing measures of physical (in)activity in one or more domain. These data covered 43 countries and 13 subregions. However, not all studies met the inclusion criteria and for some studies we were unable to obtain data in the desired format within the study time frame. Thus, our final analyses were conducted using 17 data sets for discretionary-time activity, two data sets for work-related activity and five data sets for transport-related physical activity representing 34 countries across 10 subregions. Figure 10.4 illustrates data coverage by country showing those countries that had data that met our inclusion criteria. Table 10.2 shows the proportion of the adult population for which we had data for each subregion (calculated by 12 age and sex categories).

**Figure 10.4** Exposure data coverage by country[a]




[a] Reflects data found by February 2002; other data have subsequently been identified.

**Table 10.2** Proportion of the adult population for which there were data on physical inactivity, by subregion

| *Subregion* | | *Population in subregion (000s)* | *% population within subregion covered with data* |
|---|---|---|---|
| AFR | D | 164 917 | 0 |
| | E | 192 766 | 15 |
| AMR | A | 255 419 | 96 |
| | B | 297 674 | 48 |
| | D | 44 658 | 34 |
| EMR | B | 86 854 | 7 |
| | D | 204 038 | 21 |
| EUR | A | 342 220 | 87 |
| | B | 161 213 | 0 |
| | C | 197 8934 | 63 |
| SEAR | B | 206 871 | 0 |
| | D | 818 521 | 0 |
| WPR | A | 129 888 | 65 |
| | B | 1 131 474 | 85 |

Table 10.3 provides an overview of the studies reviewed with details on the data source, sample characteristics and the domains of physical activity assessed by country and subregion. Overall, over 90% of the data sources comprised nationally representative samples and all data were collected using a random sampling methodology. Sample sizes ranged from 226 in Ethiopia (Alemu and Lindtjorn 1995) to 16 000 in China (Du et al. 2002) with the majority of studies including between 2000 and 4000 subjects. Most data were collected as part of either national surveys or ongoing monitoring systems or as part of a research project. There is one example of data from a commercial marketing company (Instituto Gallup De La Argentina 2001) and one example of a large multi-country study (Martinez-Gonzalez et al. 2000). The foci of research studies were most often cardiovascular disease, hypertension or diabetes. All data were collected after 1990.

The majority of data were collected using a questionnaire assessing multiple lifestyle risk factors although several studies collected data on physical activity only (e.g. Australia). Only a few studies assessed occupational activity as a separate domain and typically these questions assessed prevalence of three types of occupational activity, for example "mostly walking", "mostly standing" or "mostly heavy labour". Very few data were found on transport-related activity. Specific items on transport-related activity were included in only one of the health surveys (China) (North Carolina Population Center 2001b) although several other countries included walking or cycling for transport within the context of their physical activity questions. No studies were found reporting national data on physical activity in the domestic domain

**Table 10.3** Summary of sources of exposure data, by subregion

| *Subregion* | *Country* | *%*[a] | *Author* | *Year of data* | *Sample size* | *Sampling frame* | *Response rate* | *Data obtained by domain*[b] *L* | *O* | *T* | *D* | *M* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *African Region* | | | | | | | | | | | | |
| AFR-E | Ethiopia[c] | 18 | Alemu and Lindtjorn (1995) | 1991 | 226 | Random selection of households | Not reported | | | | | ✓ |
| | South Africa | 15 | Steyn et al. (1991) | 1990 | 986 | Random, stratified, proportional sample of households | Not reported | ✓ | × | | | |
| *Region of the Americas* | | | | | | | | | | | | |
| AMR-A | Canada | 10 | Health Canada (2000) | 1998 | 6 414 | Random digit dial, sampling of households, stratified by region | 58% | ✓ | × | | | |
| | USA | 87 | Ham (2001a) | 2000 | 7 529 | Random digit dial sampling of households stratified by state | 60% | ✓ | | | | |
| | USA | 87 | Ham (2001b) | 1995 | 42 000 households | 24-hour travel diary | Not reported | | | ✓ | | |
| | USA | 87 | Macera et al. (2001) | 1999–2000 | 7 529 | Random digit dial sampling of households in the 48 continuous states | . . . | | | ✓ | | |
| AMR-B | Argentina | 9 | Gallup Argentina (2001) | 2001 | 1 247 | Multistage random stratified sample system | Not reported | ✓ | | | | |
| | Brazil | 41 | Datafohla (1997) | 1997 | 2 054 | Not reported | Not reported | ✓ | | | | |
| | Chile | 4 | Jadue et al. (1999) | 1996–1997 | 3 120 | Random stratified sample from 4 zones in selected area | 40% | ✓ | | | | |
| AMR-D | Peru | 38 | Cortez et al. (2002) | 1999 | NA | Random sampling | Not reported | ✓ | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Eastern Mediterranean Region* | | | | | | | | | | |
| EMR-B | Saudi Arabia | 13 | al-Refaee and al-Hazzaa (2001) | 2000 | 1 333 | Random selection of 3 public and 3 private institutions and random distribution to employees | 75% | ✓ | | |
| EMR-D | Egypt[c] | 22 | Herman et al. (1995) | 1991–1994 | 4918 | Systematic 1/3 of households from eight randomly selected areas within 3 chosen metro areas | 81% | | | ✓ |
| *European Region* | | | | | | | | | | |
| EUR-A | 15 European countries[d] | 92 | Martinez-Gonzalez (2000) | Spring 1997 | Median across 15 countries = 1 003 | Multi-stage stratified cluster sampling | Quota system —no data on respondents available | ✓ | | |
| | 8 European countries[e] | 60 | Pucher and Dijkstra (2000) | 1995 | Not available | Multiple sources of travel survey data which varied between countries | Not available | | ✓ | |
| | United Kingdom | 14 | Dept for Transport, Local Government and the Regions (2002) | 1997–1999 | Not available | Results of national travel survey | Not available | | ✓ | |

*continued*

**Table 10.3** Summary of sources of exposure data, by subregion (*continued*)

| *Subregion* | *Country* | *%*[a] | *Author* | *Year of data* | *Sample size* | *Sampling frame* | *Response rate* | *Data obtained by domain*[b] *L* | *O* | *T* | *D* | *M* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *European Region* | | | | | | | | | | | | |
| EUR-C | Estonia | 1 | Pomerleau et al. (2000) | Summer 1997 | 2 018 | Simple random stratified sample from register | 67% | ✓ | × | | | |
| | Latvia | 1 | Pomerleau et al. (2000) | Summer 1997 | 2 303 | two stage sampling | 78% | ✓ | × | | | |
| | Lithuania | 2 | Pomerleau et al. (2000) | Summer 1997 | 2 140 | Simple random sample from register | 73% | ✓ | × | | | |
| | Russian Federation | 63 | Cockerham and Sneed (2001) | 1995 | 8 402 | Random national sample | Not available | ✓ | | | | |
| *South-East Asia Region* | | | | | | | | | | | | |
| SEAR-D | Bangladesh | 10 | Hypertension Study Group (2001) | Dec 1999–Feb 2000 | 723 | Random multistage cluster sampling within selected site | Not reported | | | | | × |
| | India | 82 | Hypertension Study Group (2001) | Dec 1999–Feb 2000 | 723 | Random multistage cluster sampling within selected site | Not reported | | | | | × |
| | India | 82 | Singh et al. (1998) | 1997 | 1 769 rural<br>1 806 urban | Random multistage cluster sampling within selected sites | 81% rural;<br>91% urban | | | | | × |
| | India | 82 | Gupta et al. (1994) | 1993 | 1 150 | Random sampling | Not reported | | | | | × |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Western Pacific Region* | | | | | | | | | | |
| WPR-A | Australia | 12 | Armstrong et al. (2000) | 1999–2000 | 3 841 | Random sample of household from white pages | Not reported | ✓ | | |
| | Australia | 12 | Transport-Travel Demand Management (2000) | 1997–1998 | . . . | Randomly selected households | Not reported | | | ✓ |
| | Australia | 12 | Bull et al. (2000) | 1999–2000 | 3 178 | Stratified random sampling of household from white pages | 46% | | | ✓ |
| | Japan | 84 | Iwai et al. (2000) | 1992–1994 | 1 893 | Stratified random sample from registry of 9 rural and 4 urban selected communities | 60% | ✓ | | |
| | New Zealand | 2 | Hillary Commission (1998) | 1997 | 5 470 | Multi-staged random cluster sampling of households | 68% | ✓ | | |
| WPR-B | China | 85 | Ham (2001c) | 1997 | 16 000 | Multi-staged random cluster sampling of household of nine Provinces | Not available | ✓ | ✓ | ✓ |
| | China | 85 | Li Xiang-ru et al. (2001) | 1996 | 8 000 | Multi-staged random cluster sampling | Not available | ✓ | | |

Key: ✓, data included; X, data not included; L, leisure (discretionary) time; O, occupational; T, transport; D, domestic; M, multiple domains included in one/two question(s).

[a] Percentage of the total population in each region that each country represents.

[b] Data included means data were used as presented in publication and/or data were obtained in format for comparison; data not included means data were not published and/or were unavailable in comparable format.

[c] Data used only in post hoc assessment of final predicted estimates of physical inactivity.

[d] Country (sample size): Austria (982), Belgium (1147), Denmark (979), Finland (1003), France (1159), Germany (1011), Greece (1011), Ireland (1001), Italy (1000), Luxembourg (512), Netherlands (1010), Portugal (1007), Spain (1000), Sweden (1001), United Kingdom (1490).

[e] Austria, Denmark, France, Germany, Italy, Netherlands, Sweden, Switzerland.

alone. Like transport, domestic activities were sometimes included within the context of broader questions, particularly in instruments developed for use in developing countries. Details of the questionnaire, the domains and definition of inactivity for each data set included in the analyses are provided in Tables 10.4–10.6.

Below are brief summaries of the data found and included, described by geographical region.

*AFRICA*

Finding data on physical activity from countries in the African Region was most difficult.

Several studies were found for various sub-populations in South Africa (Levitt et al. 1993, 1999; Sparling et al. 1994; Steyn et al. 1985, 1991). But these were regional studies with modest sample sizes. In the absence of a single study with a nationally representative sample, published data from the larger, more recent risk factor study in a black population (known as the Black Risk Study, BRISK) (Steyn et al. 1991) were selected to represent the black South African population. Estimates of inactivity among the white South African population were imputed from American data after a qualitative assessment (Lambert 2001) of the similarities in urban lifestyles. Given national estimates from the United States include white and non-white populations, the extrapolation to white south Africans may slightly underestimate levels of activity. This approach adds greater uncertainty to the estimates for this region and this is addressed in later sections.

Data from two small studies, one in rural Ethiopia (Alemu and Lindtjorn 1995) and the other in the United Republic of Tanzania (Aspray et al. 2000), provided a useful post hoc validity check on our final estimates of discretionary-time inactivity. Both studies assessed physical activity across multiple domains that could not be disaggregated.

No data were found to represent those countries in the AFR-D subregion. Two studies reported data from Nigeria (Ezenwaka et al. 1997; Forrest et al. 2001) and one study submitted for publication from Cameroon (Sobngwi et al. 2002) were identified but all three studies reported physical activity using different summary scores and/or units. At the time of our analyses the results from reanalysis were not available.

*AMERICAS*

Data on discretionary-time physical inactivity and work-related activity from the United States and Canada were identified for the AMR-A subregion. Both countries have established surveillance systems collecting nationally representative data on patterns of physical activity (C. Craig, unpublished data, 2001; S. Ham, unpublished data, 2001a; Macera et al. 2001). Data on transport-related activity for the United States were available from the National Personal Transportation Survey (Federal Highway Administration Research and Technical Support Center 1997) and data for Canada were found in a cross national comparison report (Pucher and Dijkstra 2000). No data were found for Cuba, the third country in this subregion.

For the AMR-B subregion national data on physical activity were found for Argentina, Brazil and Chile. In Brazil multiple data sets were found for different cities including Porto Alegre (Duncan et al. 1993) and São Paulo (Andrade et al. 2001). However data from the most recent, largest, most representative study, with sampling from 98 cities across Brazil was selected (Datafohla 1997). Data for Argentina were obtained from a recent national Gallup Poll that included one item on physical activity (Instituto Gallup De La Argentina 2001). Data for Chile were obtained from a recent published study conducted in a metropolitan area of Valparaiso. (Jadue et al. 1999) Two studies from Peru with data on work and discretionary-time activity were identified for AMR-D (E. Jacoby, unpublished data, 2000). Only the data on discretionary-time activity were available for inclusion.

### *Eastern Mediterranean*

Only two studies were found reporting data for physical activity EMR-B and EMR-D and neither study provided national estimates. One study from Saudi Arabia reported estimates for only discretionary-time inactivity in male adults (al-Refaee and al-Hazzaa 2001). While these data are limited in both domain and are for males only, the questions were deemed comparable and due to the lack of any alternative data they were included for EMR-B. The second study reported data on physical activity from a large sample of adults in a region of Egypt (the city of Cairo and surrounding villages) (Herman et al. 1995). The measure of inactivity assessed discretionary-time, transport and work-related activity in combination. Because it was not possible to disaggregate these components these data were used only as a post hoc check of the final predictive model.

### *Europe*

Although several individual European countries have collected data on various domains of physical activity in recent years (Hassmen et al. 2000; MacAuley et al. 1996, 1998) we selected a recent, large, multi-country study ($n$ = 15 239) assessing both discretionary-time and work-related physical activities (Institute of European Food Studies 2001). The study was selected for inclusion because it collected national representative samples from 15 countries and data were collected within a defined period of time using the same measurement instrument. The Physical and Nutrition European Union data set (known as PAN EU) provided 87% coverage of EUR-A; however these data were collected by commercial marketing companies in each country and there were no available data on the response fraction. This concern increases uncertainty around these estimates but the data were deemed more comparable than using a larger number of country-specific estimates, collected using a variety of instruments and providing less coverage of the EUR subregions.

Data on transport-related activity are likely to exist for many European countries at either a national or regional level, often in departments of transportation or planning databases. However, these data remain difficult to locate and require translation. In lieu of obtaining these data directly we used a recent report that provided national estimates of walking and cycling for several European countries and Canada (Pucher and Dijkstra 2000).

No data were found for EUR-B. Data from the MONICA project that included two sites in Poland were considered, but were not nationally representative and were therefore excluded.

One study reported data from three countries in EUR-C, namely Estonia, Latvia and Lithuania (Pomerleau et al. 2000). Two sources were identified for data on physical activity in the Russian Federation. An unpublished research study investigated patterns of activity in an adult population in Moscow (Zabina et al. 2002) and a publication using data from the Russian Longitudinal Monitoring Survey (RLMS) (North Carolina Population Center 2001a). We were unable to complete analyses of the most recent RLMS data (1998/2000) and therefore selected the published estimates from survey six in 1995 and we were provided with additional unpublished analyses from this data set (Cockerham and Sneed 2001). Combined the two sources of data provide 63% coverage of EUR-C. No data were found on transport-related activity for EUR-C.

#### *South-East Asia*

Our search found only a few studies with data on patterns of physical activity in India (Gupta et al. 1994; Singh et al. 1998) and one study with data from Bangladesh (Hypertension Study Group 2001). Other contacts through international agencies and electronic listserve identified several studies with unpublished data although none of these included nationally representative samples (Misra et al. 2001; K. Reddy, unpublished data, 2001). One study investigated an urban slum population (A. Misra, unpublished data, 2001) and another a population selected from an industrial workforce (K. Reddy, unpublished data, 2001). Both studies provided us with additional unpublished analyses, and we attempted to create a weighted (by urban and rural) national estimate. However, the results from these studies showed no clear pattern and we had low confidence in our estimate. Therefore, these data were not used in the final analyses. The small, published study with a population of older adults from rural and urban towns in Bangladesh and India was considered for SEAR-D. However, on close inspection these data were considered insufficient for inclusion.

*WESTERN PACIFIC*

Australia and New Zealand both have established health and population surveillance systems and from time to time conduct national surveys specifically aimed at assessing patterns of physical activity. Data from these specific surveys were selected for our analyses (Armstrong et al. 2000; Hillary Commission 1998). No national data on transportation activity were found for this region, thus we substituted data on cycling and walking for transport from a combination of two reports from Australia; one included a large survey with a representative sample of the population in Western Australia (Bull et al. 2000) and the other included data from a transportation project also undertaken in Western Australia (Travel Demand Management 1999).

Two studies published in English were found reporting data on discretionary-time physical activity in Japan (Arai and Hisamichi 1998; Kono et al. 1999) and translation of data from another source was also provided (N. Murase, unpublished data, 2001). However, we chose to include data from the larger Japanese Lifestyle Monitoring Study (Iwai et al. 2000) even though only discretionary-time physical activity was assessed in a middle-aged adult population (40–60 years). A small study in Singapore with data from women only was also found but after considering the instrument and definition of inactivity it was excluded.

Subregion WPR-B is represented by data found from China. Nine published studies were identified (Bell 2001; Hong et al. 1994; Hu et al. 1997, 2002; Matthews et al. 2001; Paeratakul et al. 1998; Pan et al. 1997; Yu and Nissinen 2000; Yu et al. 2000) but excluded in preference for recent data from the China Health and Nutrition Survey (CHNS) (North Carolina Population Center 2001b). Micro data were available online (http://www.cpc.unc.edu/) and we conducted additional analyses on physical activity across different domains (Ham 2001c). Additional data from the State Sport General Administration of China were also found and these suggested notably higher estimates of discretionary-time activity compared with CHNS. After a careful review of the two questionnaires and input from experts familiar with China, the average of the two studies was used to estimate the prevalence of inactivity in China (Wang 2002). These data provided 85% coverage of WPR-B.

## 2.5 COMPARABILITY OF INSTRUMENTS ASSESSING PHYSICAL ACTIVITY AND ESTIMATES OF EXPOSURE AMONG INCLUDED STUDIES

Tables 10.4, 10.5 and 10.6 provide a summary of the data sets used to assess physical (in)activity in discretionary-time, work and transport domains, respectively. For each data source a brief description of the question and the definition of inactive is provided. Below is a summary on the comparability of the final selection of studies in each domain.

**Table 10.4** Summary of questions used to assess discretionary-time physical (in)activity

| | | | | | Discretionary-time (in)activity | |
|---|---|---|---|---|---|---|
| *Subregion* | *Country* | *Reliability* | *Validation* | *Study title/instrument (reference)* | *Method of assessment* | *Definition of inactive* |
| AFR-E | Ethiopia | Not available | Not available | Borana Health and Nutrition Study (Alemu and Lindtjorn 1995) | Seven-day recall via a series of close-ended questions. Participants were interviewed for 7 consecutive days every three months for one year. Activities coded as sleep (1 MET), light (1.5 METs), moderate (4 METs), hard (6 METs), very hard (10 METs) | Reported mean day EE in kcals/day and kcals/kg per day. (Reanalysis for this work defined inactive as no hard or very hard activities over a 7-day period) |
| | South Africa | Not available | Not available | BRISK study (Steyn et al. 1991) | Question: After working hours do you get any regular (more than twice/week) exercise? If yes, is it light or strenuous? | No exercise outside of working hours |
| AMR-A | Canada | Not available | Not available | 1998 Physical Activity Monitor (C. Craig, unpublished data, 2001) | Prompted recall of participation in approximately 25 different activities over last 12 months. For each activity reported, number of times in last 12 months and average duration/occasion were recorded | Energy expenditure equal to or less than 0.5 KKD (kcals/kg per day) |
| | USA | Kappa = 0.57–0.77 | Not available | National Physical Activity Survey 1999–2000 (Ham 2001a) | Question: In last month, have you participated in any physical activities or exercises such as brisk walking, bicycling, vacuuming, gardening, or anything else that causes small increases in breathing or heart rate? If yes, type, distance, usual minutes and frequency are recorded | No activities reported |

| | | | | | | |
|---|---|---|---|---|---|---|
| AMR-B | Argentina | No | No | August Omnibus Wave-Gallup Poll (Instituto Gallup De La Argentina 2001) | Question: Do you regularly practice some type of physical activity? If yes, what (choice of 8 activities or "other")? | No practice of regular physical activity |
| | Brazil | No | No | Brazil – 98 Cities Project (Datafohla 1997) | Prompted recall of participation in 15 sports and activities (+ "other"). If yes, frequency during last month and pattern of participation over last 10 years was recorded | No activities reported |
| | Chile | Pearson correlation for leisure index 0.74–0.83 | Pearson correlation r = 0.83 (VO2 Peak) 0.44–0.56 (EE from 3-day diary) | Baecke Questionnaire of Habitual Physical Activity (Jadue et al. 1999) | Participation in sports assessed in two ways. One question asked Do you play sports? If yes, type, frequency, duration recorded. Second question asked During leisure time I play sports? Response is on 5-point Likert scale (never–very often) | Persons who "never" do exercise (sports) regularly in their free (leisure) time |
| AMR-D | Peru | Not available | Not available | National Living Standards Measurement Survey (Cortez et al. 2002) | Question: In the last month, did you practice any sport such as soccer, volleyball, jogging or walking, among others? If yes, How many times during the last month did you participate in these activities? | No practice of physical activity in leisure time in last month |
| EMR-B | Saudi Arabia | Not available | Not available | Research project using original questions (al-Refaee and al-Hazzaa 2001) | Question: Do you currently do any type of physical activity in a typical week? If yes, Is it regular? How many days? For how long? What kind? | No current physical activity at all (no walking, jogging, swimming, gardening, yard work or any sporting activity) |
| EMR-D | Egypt | Not available | Not available | Research project using original survey (Herman et al. 1995) | One question assessed activity "outside the job" (including transportation to and from work, sporting activities, and other leisure time physical activity). Response was on a 4-point scale | No physical activity weekly |

*continued*

**Table 10.4** Summary of questions used to assess discretionary-time physical (in)activity (*continued*)

| | | | | | *Discretionary-time (in)activity* | |
|---|---|---|---|---|---|---|
| *Subregion* | *Country* | *Reliability* | *Validation* | *Study title/instrument (reference)* | *Method of assessment* | *Definition of inactive* |
| EUR-A | European Union[a] | Not available | Not available | Pan-EU survey (Institute of European Food Studies 2001) | Question: At present, in an average week, which, if any of the following activities do you participate in? (Respondents prompted with list of 20 sports which included walking for 30 mins and gardening + "other"). For each activity, frequency and duration per week recorded | Zero hours of activity per week |
| EUR-C | Estonia, Latvia, Lithuania | Not available | Not available | Research project using original survey (Pomerleau et al. 2000) | Exact question not specified but responses coded as low, moderate (walking, cycling or other light activities >4 hrs/wk), high (jogging other sports, heavy gardening >4 hrs/wk) and very high (hard training/sports >1 time/wk) | Lowest category: low (i.e. reading, watching television or other sedentary activities) |
| | Russian Federation | . . . | Not available | Russian Longitudinal Monitoring Survey 6 (Cockerham and Sneed 2001) | Question: Which description characterizes your physical exercises best not counting at work? Seven response categories which combine intensity of activity and frequency | Published data used. Does not engage in physical activities. (Reanalysis combined lowest two categories namely "does not engage" and "light exercise for relaxation <3 times/week") |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Australia | 3-day test–re-test Intra class Correlation r = 0.71–0.86 | Not available | 1999 National Physical Activity Survey (Armstrong et al. 2000) | Four questions assess activity: walking (for recreation/exercise or to get to or from places), vigorous gardening or heavy work around the around the yard, moderate activities (gentle swimming, social tennis, golf, etc.) and vigorous activities (jogging, cycling, aerobics, competitive tennis). Frequency and total time during the last week recorded | No participation in moderate or vigorous activities or walking. (Gardening excluded from analyses) |
| WPR-A | Japan | One month test–re-test: light r = 0.73; total r = 0.92 | Tested against VO2 Pearson correlation r = 0.47 | Japan Lifestyle Monitoring Study – (Minnesota leisure-time questionnaire) (Iwai et al. 2000) | Question: How often have you engaged in any habitual leisure-time physical activity? List of activities provided and for each activity, frequency and duration recorded | No habitual leisure-time physical activity within last 12 months |
| | New Zealand | Not available | Not available | 1998 Sport and Physical Activity Survey (Hillary Commission 1998) | Prompted recall of activities using list of 42 activities (including walking >30 minutes, walking 10–30 minutes and gardening). Frequency over last 12 months, last 4 weeks, last 2 weeks, and last 7 days recorded. Duration for each activity over last 7 days recorded | No activity in last 4 weeks |
| WPR-B | China | Not available | Not available | China Health and Nutrition Survey 2001 (Ham 2001c) | Prompted recall of 5 activities (+ "other") undertaken more than 12 times in last year. Time/week for each activity recorded | No activity undertaken more than 12 times in the last year |

Key: EE, energy expenditure; MET, metabolic equivalent. VO2, oxygen consumption.

[a] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.

**Table 10.5** Summary of questions used to assess work-related physical (in)activity

| | | | | | Occupational activity | |
|---|---|---|---|---|---|---|
| *Subregion* | *Country* | *Reliability* | *Validation* | *Study title (reference)* | *Method of assessment* | *Definition of active* |
| AFR-E | South Africa | Not available | Not available | BRISK study (Steyn et al. 1991) | Question: Does your work involve mostly: 1) primarily sitting/standing; 2) a lot of walking; 3) hard physical (sweat) work? | Category 3: hard physical (sweat) work |
| AMR-A | Canada | Not available | Not available | 1998 Physical Activity Monitor (C. Craig, unpublished data, 2001) | One question assessed activities undertaken at home or at work like lifting boxes, carrying objects, climbing stairs or walking as part of your job or chores. Frequency was recorded. Response scale was: 1) almost all the time; 2) almost three-quarters; 3) almost half of the time; 4) about a quarter and/or almost none of the time | Category 1: almost all the time |
| AMR-A | USA | Not available | Not available | National Physical Activity Survey 1999–2000 (Ham 2001b; Macera et al. 2001) | Question: When you are at work which of the following best describes you: Mostly sitting or standing? Mostly walking? Mostly heavy labour? | Middle and upper category: mild physical exertion and heavy physical exertion |
| EUR-A | European Union[a] | Not available | Not available | Pan-EU survey (Institute of European Food Studies 2001) | One question assessed typical day's activity (either at work, college, in the office or at home). Categories of responses: 1) sitting down at work; 2) standing or walking around; 3) more physical work than any of the above. Approximate number of hours/day recorded | Category 3: more physical work than sitting down, or standing or walking around for 3–6 hours |

| | | | | | | |
|---|---|---|---|---|---|---|
| EUR-C | Estonia, Latvia, Lithuania | Not available | Not available | Research project using original survey (Pomerleau et al. 2000) | Question not specified but responses coded as low; moderate (mixed sedentary and standing work); high (work requires a lot of walking, lifting, carrying–examples given include heavy housework); and very high (heavy manual work and example occupations given) | Categories: high (work requiring a lot of walking, lifting or carrying) or very high |
| WPR-A | Japan | Not available | Not available | Japan Lifestyle Monitoring Study (Iwai et al. 2000) | Frequency and average duration of various types of labour and other activities on the job, including household activities, for every two months within the last 12 months were queried. Responses were classified into 4 categories according to intensity: sedentary (1.5 METs), standing/walking (2.5 METs), moderately strenuous work (4.5 METs), strenuous work (7.5 METs). A total work activity score was calculated. Lists of activities for 5 major types of businesses were used as prompts | Strenuous work[b] |
| WPR-B | China | Not available | Not available | China Health and Nutrition Survey 2001 (Ham 2001c) | Time spent in three categories of activities during a work day assessed. Categories: light or very light; moderate; heavy or very heavy. Examples provided for each category | Categories: heavy or very heavy |

Key: MET, metabolic equivalent.

[a] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.

[b] Prevalence estimates for work-related activity were not calculated and were thus unavailable for inclusion.

**Table 10.6** Summary of questions used to assess transport-related physical activity

| | | | | | Transport-related physical activity | |
|---|---|---|---|---|---|---|
| *Subregion* | *Country or area* | *Reliability* | *Validation* | *Study title (reference)* | *Method of assessment* | *Calculation and/or definition of active* |
| AMR-A | USA, Canada | Not available | Not available | 1995 National Personal Transportation Survey (Ham 2001b) | Travel diary[a] | Proportion of adults reporting greater than one walk/cycle trip |
| EUR-A | Netherlands, Germany, England and Wales, France, Italy, Switzerland, Austria, Sweden, Denmark | Not available | Not available | Cross National Comparison (Pucher and Dijkstra 2000) | Travel diary[a] | Proportion of all trips undertaken by walking/cycling used to estimate proportion of adults walking and cycling |
| | United Kingdom | Not available | Not available | National Transport Survey (Department of Transport Local Government and the Regions 2002) | Travel diary[a] | Proportion of adults reporting greater than one walk/cycle trip |
| WPR-A | Australia | Not available | Not available | Physical Activity Levels of Western Australian Adults, 1999 (Bull et al. 2000) | Two questions asked: . . . in the last week . . . have you done continuously for ten minutes or more 1) cycle for transport; 2) walk for transport? Response was yes/no | Active defined as a yes response |
| | Australia | Not available | Not available | TravelSmart 2010 (Travel Demand Management 1999) | Travel diary[a] | Proportion of adults reporting greater than one walk/cycle trip |
| WPR-B | China | Not available | Not available | China Health and Nutrition Survey, 2001 (Ham 2001b) | Two questions assessed walking time of round trip to work, school, shopping in hour and minutes; biking time of round trip to work, school, shopping in hours and minutes | Active defined as one or more trips |

[a] Typically the number of trips are recorded over a 3–7 day period in the travel diary. A trip is defined to be any "time [a person] went from one address to another in a vehicle or by walking or biking. Each stop [made] is a separate trip, including picking up or dropping off someone".

*DISCRETIONARY-TIME (IN)ACTIVITY*

The 17 studies providing data for 33 countries that were included in this report used 17 different measures to assess physical activity in discretionary time (Table 10.4). Seven studies assessed participation using an instrument comprising a list of specific activities (i.e. a prompted approach $n = 6$) or by asking the respondent about "any activities" and recording the type (i.e. unprompted approach $n = 1$). Both approaches assessed frequency and duration (as detailed in Table 10.1 and ascribed questionnaire format 1 and 2, respectively).

Nine studies used either a single question or a small number of questions with either open or closed response format (Table 10.1, format 3). These instruments comprised the most diverse set of questions and rarely were the reliability or validity properties of the instruments reported. Only one study used an instrument that captured time spent doing categories of activities (format 5), where categories were defined by the intensity of activity (e.g. moderate-intensity and vigorous-intensity). Only one study used a detailed recall over the past seven days (format 4).

Despite these 17 questionnaires appearing quite different, closer inspection revealed considerable similarity in what each measure attempted to assess. Moreover, the definitions of inactive (level 1 exposure) were very comparable. Three quarters of the studies ($n = 14$) used "no", "none", "never" or "zero" as part of their quantification of inactive. In one study (C. Craig, unpublished data, 2001) inactive was defined on a continuous scale (as less than 3 kcals/kg per day). Three studies used the lowest category of activity as described in their question (Cockerham and Sneed 2001; Craig 2001; Pomerleau et al. 2000).

The degree of similarity across the definitions of inactive was sufficient for these data to be included in our analyses. However, it is recognized that this comparison is not perfect. Walking and gardening were included in some studies and not others; nor were these activities always defined the same way. Furthermore, the reference time frame and definition of "regular" used in questions were not always consistent. These differences remain limitations to the comparison of data on physical activity.

*WORK-RELATED (IN)ACTIVITY*

Table 10.5 provides a summary of the questions used to assess work-related physical (in)activity in each study for which we had at least some data for consideration. Three of the seven instruments were used in formats 1 or 2 and asked about three types of work activities, namely walking, standing and hard (or heavy) physical work/labour (e.g. EU, South Africa, the United States). Three studies used an instrument (format 3) assessing different categories of intensity (e.g. light, moderate and heavy) and this was deemed comparable to format 1 and 2 instruments. The remaining instrument captured frequency of different types of work-related activity (Iwai et al. 2000).

While there were clear differences in the format of the instruments used to assess this domain, the more significant problem was that "non-work" activities were also included in the wording of items and thus the physical activity prevalence estimates. For instance, Canada included "chores", and this may have been interpreted as household (domestic tasks) and Japan specifically cited "household activities". The wording and consequently broader scope of the questions severely limited the comparability of these measures of work-related physical activity—so much so that we concluded that only the questions used in the studies from the United States and China were sufficiently similar to allow comparison and thus only these data were used in subsequent analyses.

*Transport-related (in)activity*

Our search for data on transport-related physical activity, and more specifically patterns of cycling and walking to get to and from places, found very few national data sets. It is acknowledged that many countries collect these data as part of national or regional transportation planning and evaluation activities. However, it was beyond the scope of this project to complete an exhaustive search of these sources. Table 10.6 presents details of the six sources used in this study covering 15 countries.

Transportation data can be collected either by prompted recall during a telephone interview or from diaries completed daily over a specific time frame (usually 3–7 days). Trip origin and destination are usually recorded as well as trip mode and duration. This approach is common in developed countries and examples include the National Personal Transportation Survey in the United States (Federal Highway Administration Research and Technical Support Center 1997) and similar instruments used in several European countries (Pucher and Dijkstra 2000) and Australia (Travel Demand Management 1999). In contrast the Health and Nutrition Survey in China included very specific questions to capture the number of walk or cycle trips to a range of specific destinations.

Integrating measures of transport-related physical activity into the assessment of total physical (in)activity is at a very early stage. For this project we were limited to sources of data from three transportation surveys and one health survey. It is acknowledged that other studies previously mentioned and included under other domains may have captured all or some walking trips, either by using a distinct question or by specifying walking as an example of moderate-intensity activity (Armstrong et al. 2000). The same possibility exists for some cycling trips. However, in these cases it was not possible to disaggregate the activity into separate domains. Clearly further development of a standard set of questions for transport-related physical activity is required.

With the exception of China and the United States, all the studies used for this project presented data as "percent of trips" not as a proportion of people undertaking trips. In lieu of obtaining data in the latter format we analysed data from the United States to help derive an estimate from per cent of trips. This method is described in full detail in later sections.

#### *Domestic-related (in)activity*

No data were obtained on physical (in)activity in the domestic domain. We found several studies that did include questions to assess this domain but the data were not reported. Like transport-related activity, some domestic-related activity may have been captured because of the wording of questions or the examples provided. For instance, "housework" could be specified as a moderate-intensity activity in addition to examples of sports and recreational pursuits. In this situation, it was usually impossible to disaggregate the data and, if used, this data could potentially lead to erroneous estimates.

Due to the lack of sufficient data in this domain it was not possible to estimate the magnitude of domestic physical activity or inactivity. It is recognized that this is an important domain and therefore a significant limitation to our final estimates. Moreover, it is highly likely that there is considerable variation in levels of domestic activity between developing and developed countries, within countries, between males and females and across ages. The magnitude and direction of these differences are not well known. Some data are available from studies investigating energy intake and expenditure but these studies usually investigate very specific populations and provide too few data to generalize.

#### *Combination measures of (in)activity across domains*

Several countries used instruments that assessed physical activity across multiple domains. Often these questions presented a brief description and respondents chose a category (e.g. in Egypt) (Herman et al. 1995). In one case very detailed data were obtained via a seven-day recall instrument and the final analyses combined all activity across all domains (e.g. in Ethiopia) (Alemu and Lindtjorn 1995). Data from these approaches were excluded from our estimates in the specific domains. However, where appropriate these data were used post hoc to assess the fit of our final predicted estimates.

### 2.6 Treatment of data

#### *Dealing with data reported for different age categories*

Much of the data obtained was not available using the same cut-point for age categories. The first and preferred solution involved contacting the original investigators and requesting data analysed by the relevant age groups. Where this was not possible or where data were no longer accessible, an indirect method was used to compute age-specific estimates, by assuming uniform distribution of population and exposure in one-year increments of each age category.

Where data were available for only some of the age groups included in the lower and upper age categories used in this report (e.g. 15–29 years, 60–69 years, 70–79 years) the obtained prevalence estimate was applied to all years in the category. For example if data were available for only those aged 60–65 years it was applied to our 60–69 year category, and also extrapolated to older age groups such as 70–79 or ≥80 years. The effect of this is to slightly underestimate inactivity in the older years within an age category (inactivity usually increases with age) and slightly overestimate the prevalence of inactivity within the youngest age category.

*Dealing with data from non-nationally representative samples*

Several data sets did not come from nationally representative samples. In these instances, descriptions of the study sample and information on the age, sex, ethnic/racial and rural/urban profile of the country were used to create adjusted weighted national estimates. For example, these steps were undertaken with data from Bangladesh and India, which were samples from older adults in urban and rural towns, and also for transport data from Australia that were weighted to form a national estimate.

*Dealing with missing data by sex, age and subregion*

Table 10.7 provides a summary of the amount of data identified for each of the 14 subregions according to six age groups and both sexes. Of these 168 cells, 44% were missing data. For the 14 subregions, the missing cells ranged from 0% (AMR-A and WPR-B) to 100% (SEAR-B). Across subregions, missing data cells ranged from 32% for the four age groups spanning 15–69 years, and increased to 57% and 79% for the 70–79 and ≥80 age groups, respectively. These incomplete subregional by age and sex data cells presented two tasks:

- obtaining estimates for missing age and sex categories; and
- obtaining estimates for countries/subregions where no data source exists.

One approach to solving these two issues was to select the most comparable data set available and apply these values to missing cells. For example, data from EUR-C could be substituted for EUR-B, or WPR-B (which includes China) could be used to derive estimates for SEAR-B and SEAR-D. Similarly missing data for older adults in Europe could be derived from known data from the Americas. While plausible, this approach is weak because any limitations in the data for one subregion will be extended to the other. Moreover, it makes no attempt to better represent the likely differences that exist between countries.

**Table 10.7** Summary of data available by subregion, sex and age[a]

| Subregion | Countries with data | Sex | Age group (years) 15–29 | 30–44 | 45–59 | 60–69 | 70–79 | ≥80 |
|---|---|---|---|---|---|---|---|---|
| AFR-D | | Male | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Female | 0 | 0 | 0 | 0 | 0 | 0 |
| AFR-E | South Africa | Male | 14 | 18 | 18 | 16 | 1 | 1 |
| | Ethiopia | Female | 14 | 18 | 18 | 17 | 1 | 1 |
| AMR-A | Canada | Male | 96 | 96 | 97 | 97 | 97 | 88 |
| | USA | Female | 96 | 96 | 97 | 97 | 98 | 89 |
| | Argentina | Male | 51 | 54 | 56 | 17 | 0 | 0 |
| AMR-B | Chile | Female | 51 | 53 | 56 | 18 | 0 | 0 |
| | Brazil | Male | 36 | 39 | 40 | 0 | 0 | 0 |
| AMR-D | Peru | Female | 37 | 40 | 40 | 0 | 0 | 0 |
| EMR-B | Saudi Arabia | Male | 13 | 13 | 19 | 15 | 0 | 0 |
| | | Female | 0 | 0 | 0 | 0 | 0 | 0 |
| EMR-D | Egypt | Male | 21 | 22 | 22 | 21 | 22 | 0 |
| | | Female | 20 | 22 | 24 | 23 | 25 | 0 |
| EUR-A | European Union[b] | Male | 91 | 92 | 91 | 93 | 78 | 20 |
| | | Female | 91 | 92 | 91 | 92 | 78 | 24 |
| EUR-B | Estonia | Male | 0 | 0 | 0 | 0 | 0 | 0 |
| | Latvia | Female | 0 | 0 | 0 | 0 | 0 | 0 |
| EUR-C | Lithuania | Male | 63 | 64 | 64 | 60 | 58 | 56 |
| | Russian Federation | Female | 62 | 64 | 64 | 61 | 60 | 61 |
| SEAR-B | | Male | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Female | 0 | 0 | 0 | 0 | 0 | 0 |
| SEAR-D | India | Male | 0 | 0 | 0 | 0 | 0 | 0 |
| | Bangladesh | Female | 0 | 0 | 0 | 0 | 0 | 0 |
| WPR-A | Australia | Male | 15 | 96 | 98 | 97 | 10 | 0 |
| | Japan | | | | | | | |
| | New Zealand | Female | 16 | 96 | 98 | 97 | 9 | 0 |
| | Singapore | Male | 82 | 86 | 88 | 88 | 89 | 87 |
| WPR-B | China | Female | 82 | 86 | 87 | 87 | 88 | 88 |

a As % of total population in each subregion.

b Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.

An alternative approach was to develop a statistical model to predict national estimates of physical inactivity. Known correlates of inactivity at the individual level could be explored for their predictive value at the national level (e.g. level of education). In addition, a range of other parameters, possibly related to inactivity, such as indicators of economic development (e.g. per capita gross national product [GNP]), could be investigated. Using this "ecological" approach represents the first stage of the epidemiological approach to identifying and understanding the determinants of physical inactivity. Such a model was used to predict values for countries with missing data and values for missing age/sex cells in countries with only some data. This approach has the advantage of using all available, comparable data on physical inactivity to develop a statistical relationship with other indicators for which there are data available worldwide. We also had to decide whether to create a single model to predict the sum total of inactivity (i.e. inactivity across all four domains as stated in the definition of exposure) or four separate models—one for each domain. The latter approach was selected because of the complexities of the behaviour and the likelihood that different parameters may explain levels of inactivity in different domains.

### 2.7 Estimating prevalence of level 1 exposure (inactive) using regression analysis

Multivariate and linear regression analyses were used to create predictive models for discretionary-time, work-related and transport-related levels of inactivity. All data obtained from the worldwide search that met our inclusion criteria were considered for inclusion in this process. Only data that clearly represented a single domain were included in the domain-specific modelling exercise. Domestic physical inactivity could not be modelled due to insufficient data. Estimates from countries with measures of physical (in)activity that comprised multiple domains were used post hoc to assess the fit of predicted estimates of overall inactivity across all domains. Only one source of data per country was used.

From a practical stance it was necessary to treat all data within a domain as either values of exposed (namely % inactive) or unexposed (% active). In most cases we found it more convenient to work with a model predicting prevalence of doing some physical activity (unexposed) and in the final step to reverse the direction to inactivity (exposed). The exception was in the discretionary-time domain where the predictive model was developed for inactivity.

The modelling approach of level 1 exposure required six steps:

1. Create a predictive model to estimate discretionary-time physical inactivity, and subtract values from 100 to create estimates of physical activity.

2. Create a predictive model to estimate work-related physical activity.

3. Create a predictive model to estimate transport-related physical activity.

4. Sum the domain-specific estimates of physical activity and adjust for overlap across domains.

5. Scale estimates of physical activity and subtract values from 100 to compute final estimates of level 1 exposure (physically inactive).

6. Aggregate age by sex country-level estimates to create age by sex regional-level estimates.

Within each step estimates for each age (six categories) by sex (male/female) cell were modelled and predicted rather than working with and predicting only single point estimates to represent all persons from each country. Table 10.8 summarizes the potential parameters found from World Bank data (World Bank 1999) that were considered for inclusion in the models of (in)activity in each domain. Many of these potential parameters were highly associated including, for example, GNP and per cent of the population completing tertiary education (hereafter referred to as "% tertiary education") (correlation matrix not reported). Criteria for parameters were the following:

1. Parameters must be available on a national level for most countries across most regions.
2. Parameters must come from a reliable (reputable) source.
3. Parameters must be from recent sources consistent with our exposure variable.

Within each domain, predicted estimates were limited to the countries for which data on the selected parameters were available from the World Bank ($n = 146$). After completion of the first five steps, the final task was to aggregate the age-sex-country specific values to create age by sex

**Table 10.8** Summary list of potential parameters considered for modelling level 1 exposure

| *Parameter categories* | *Potential parameter* |
|---|---|
| Demographic | Country population<br>Regional population<br>Per cent urbanization<br>Typical population density experienced by an individual |
| Economic | GNP per capita<br>World Bank classification |
| Socioeconomic | Per cent completing tertiary education |
| Geographical | Subregion<br>Latitude of the country centroid |
| Climatalogical | Mean annual temperature |
| Employment | Per cent employed in agricultural sector<br>Per cent employed in manufacturing sector<br>Per cent employed in service sector |
| Energy consumption/emissions | Cars per thousand population<br>Carbon dioxide emissions |
| Data | Quality of prevalence data |

regional estimates. At this point known data replaced predicted values where available. Each of the above steps undertaken to estimate the prevalence of exposure level 1 (inactive) is described in detail below.

*STEP 1: ESTIMATING DISCRETIONARY-TIME PHYSICAL ACTIVITY*

Data by age and sex from 32 countries provided the basis for estimating the prevalence of discretionary-time physical inactivity (level 1 exposure) for 12 age-sex categories in 146 countries. A mixed model for nested, repeated measures was used to identify a model with predicted values that best approximated the data. Twelve age-sex categories were treated as repeated measures nested within each country.

The general linear mixed model is

$$Y = X\beta + Zu + e$$

where: Y = observed response variables
X = matrix of known values of covariates
$\beta$ = matrix of unknown fixed-effects parameters
Z = known design matrix of random effects
u = matrix of unknown random-effects parameters
e = error.

The model assumes that the error is independent and identically distributed (iid). A mixed model was chosen as most suitable for these data because we considered the possibility of correlation within countries (e.g. clustering of age by sex prevalences). Within-country estimates are likely to cluster because the level of economic development and culture is likely to determine if any data were available and relatively small differences in use of discretionary-time within a country; in contrast, the differences in measurement instruments and protocols would be greater between countries. In addition, using a mixed model allowed for the consideration of clustering of physical activity patterns by geographic region (our strata variable) and this was deemed desirable for the analysis. Mixed models are robust to two characteristics of our prevalence data, heterogeneous variances within clusters (e.g. countries and regions) and missing and unbalanced data. It is acknowledged that missing data may not be random. The effect of missing data is most likely to increase error in subregions with less coverage and reduce error in subregions with better coverage. We compensated for the limitation due to missing data in our calculations of age by sex by subregion estimates by increasing our 95% confidence limits (described in detail later).

A simple repeated (up to 12 age by sex cells per country) measures model is

$$y_{ij} = \mu + \alpha_{ij} + d_i + e_{ij}$$

where $\mu$ and $\alpha_{ij}$ are fixed-effects parameters,
$d_i \sim$ iid $N(0, \sigma^2)$ is the random-effect parameter, and
$e_{ij} \sim$ iid $N(0, \sigma^2)$.

Several tasks were undertaken before the multivariate modelling. Firstly, the skewed physical inactivity data available from 32 countries were transformed to obtain a more normal distribution. Various transformations were attempted but several countries (e.g. Chile, China, the Russian Federation) which had very high estimates of inactivity (ranging 85–96%) prevented any transformation from creating a truly normal distribution. Nonetheless, the square root transformation created a more satisfactory variable with a distribution closest to normal (Figure 10.5).

Secondly, we created a variable regional strata to allow countries with data within a region to have a greater influence on the predicted values of other countries in the same region. Due to the overall lack of data across the 14 subregions, five new regional strata were developed to help our analyses. These strata were defined by considering geographical location, World Bank income classification, social, religious and cultural similarities and the availability of data on exposure. The five strata are shown in Table 10.9.

*Weighting*

After some preliminary attempts at modelling discretionary-time physical activity and predicting age by sex by country estimates we introduced a weighting factor for each data set. This step was in addition to using the regional strata parameter, and weighted data to the world popula-

**Figure 10.5** Transformed age x sex estimates for discretionary-time physical inactivity data ($n$ = 276) from 31 countries

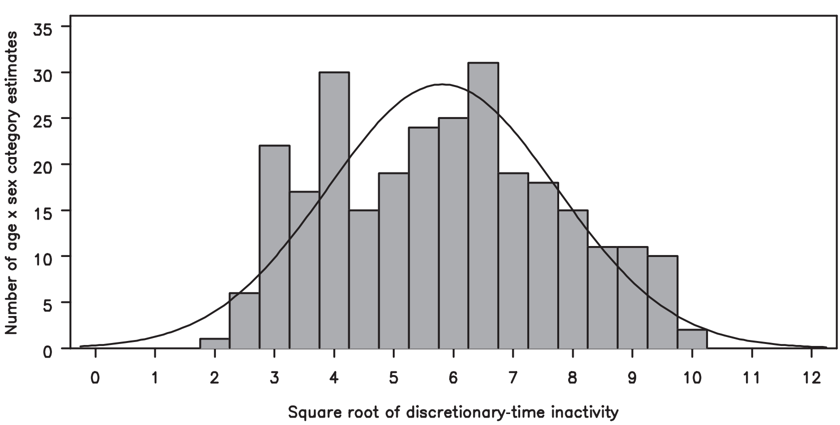


**Table 10.9** Country allocation to regional strata parameter for modelling level 1 exposure

| *Regional strata created for model* | *Countries included* |
|---|---|
| 1 Western industrialized | Western Europe (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Luxembourg, Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, Switzerland, United Kingdom); North America (Canada, USA); Australia, New Zealand |
| 2 Latin America | Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, France (Guiana), Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Netherlands, Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Suriname, Trinidad and Tobago, Uruguay, Venezuela |
| 3 Africa | Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Côte d'Ivoire, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, United Republic of Tanzania, Togo, Uganda, Zambia, Zimbabwe |
| 4 South-East Asia | Cambodia, China, Democratic People's Republic of Korea, Indonesia, Japan, Lao People's Democratic Republic, Malaysia, Mongolia, Philippines, Republic of Korea, Singapore, Sri Lanka, Thailand, Viet Nam |
| 5 Transitional nations | Eastern Europe (Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Serbia and Montenegro, The former Yugoslav Republic of Macedonia, Turkey); Central and South Asia (Bangladesh, Bhutan, India, Nepal, Pakistan); the Middle East (Afghanistan, Cyprus, Iran [Islamic Republic of], Iraq, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Saudi Arabia, United Arab Emirates, Yemen); North Africa (Algeria, Egypt, Morocco, Tunisia); and the Russian Federation |

tion (aged ≥15 years). A weighted model should produce similar parameter estimates regardless of the number of countries, or which specific countries, were included in the model. This was an important consideration because over half of the data were from China, Europe, North America and the Russian Federation. The intent was to avoid these data dominating the model and thus the final estimates.

In practice, known data from a country were weighted to the total population (by age and sex) of the regional stratum proportional to the country population in which the data were available. The sum total population was the total population (aged ≥15 years) in the 146 countries for which the independent variable (% tertiary education) was available.

Over half of all the available data on physical inactivity were from countries in the Western industrialized stratum and within this stratum these data represented 90% of the population. In the South-East Asia stratum, data were available from China, Japan and Singapore, and China represented 77% of the stratum's population. Using the weights improved the predicted prevalence estimates by allowing China to contribute to the model approximately 1.3 times its population, while limiting the influence of data from countries in the Western industrialized countries to slightly more than their population of each country (1.1 times).

The remaining strata had fewer countries with data and thus smaller proportions of the strata population were represented. In these cases, the countries with data determined the age by sex trends of inactivity while the covariate (% tertiary education) influenced the intercept for each individual country. Individual weights are not shown because they varied for each country depending on what age by sex data were available and the age by sex population of the stratum.

### *Preliminary models of discretionary-time physical inactivity*

All of the parameters listed in Table 10.8 were explored in univariate and multivariate models. As mentioned many of the World Bank indicators were correlated and if used in combination would cause problems of collinearity, or unreliable parameter estimates resulting from correlated covariates. Using % tertiary education was found to explain almost equal variance as GNP and provided smaller residuals that were more normally distributed. Education was reasonably normally distributed. The single point estimate of education per country was applied equally to the 12 age by sex cells.

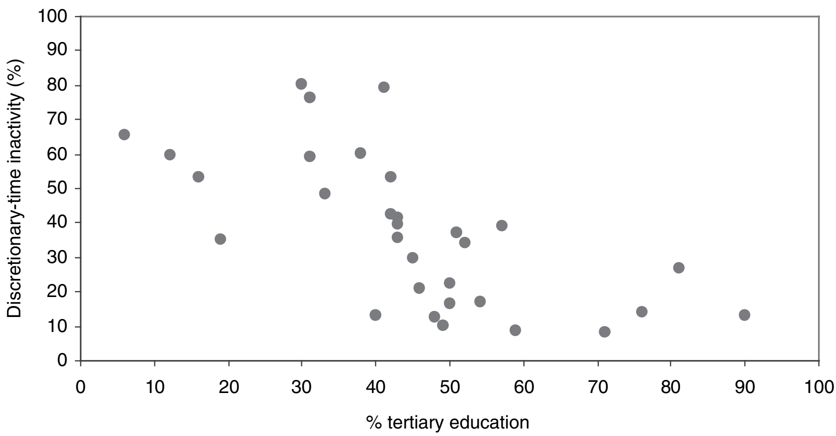
Figure 10.6 shows a plot of national estimates of discretionary-time physical inactivity by the indicator % tertiary education for 31 countries. The figure shows that countries with lower tertiary education have a higher prevalence of discretionary-time inactivity.

In addition to exploring a range of demographic, economic and development indices we tested a model that included a variable rating the "data representativeness". As discussed there is insufficient evidence on which to base judgements about different types of instruments, thus we created a variable that differentiated national sources of data from non-national (regional or metropolitan). China was coded as national because the sample was representative of 16 provinces. Including the data representativeness parameter did not, however, improve our model; thus it was removed.

### *Final model of discretionary-time physical inactivity*

The final model parameters were education (defined as % tertiary education), age, sex, region, a three-way interaction termed age x sex x region and corresponding two-way terms. This parameter allowed trends for age to vary by sex and for each different region and it helped to

**Figure 10.6** National estimates of discretionary-time physical inactivity by the indicator % tertiary education ($n$ = 31 countries)




improve the predictive power of our analysis. Available data suggest that the trend for inactivity across age can vary by sex and by region. Education allowed inactivity for each country to be based upon an external measure known to be highly associated with a number of risk factors, including discretionary-time physical inactivity, at the individual level. Other social and economic indicators were tested and some produced good results (e.g. particularly GNP per capita), but the best model fit and distribution of the residuals was obtained using the parameter education.

Applying the simple repeated measures model to estimate discretionary-time activity, we get

$$y_{ij} = m + a_{ij} + d_i + e_{ij}$$

where $y_{ij}$ is the response, prevalence estimates for age x sex x country categories;
m and $a_{ij}$ are fixed-effects parameters: intercept, age, sex, region, % tertiary education, interaction parameters;
$d_i$ is the random-effect parameter, country; and
$e_{ij}$ is error.

The final model for predicted discretionary-time physical inactivity using data obtained from the World Bank is represented by:

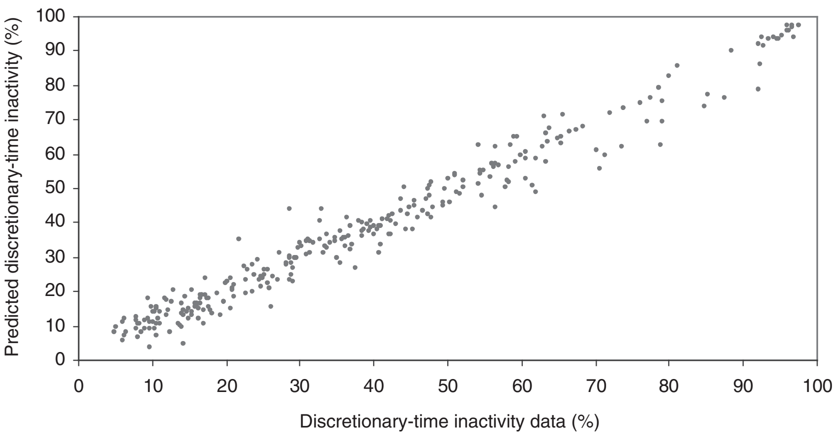
$$\begin{aligned}&\text{square root(DISCRETIONARY-TIME PHYSICAL}\\&\quad \text{INACTIVITY)}_{\text{COUNTRY,AGE,SEX}} = \alpha_i + \beta_1(\text{AGE}) + \beta_2(\text{SEX})\\&\quad + \beta_3(\text{REGION}) + \beta_4(\text{AGE} \times \text{SEX}) + \beta_5(\text{AGE} \times \text{REGION})\\&\quad + \beta_6(\text{SEX} \times \text{REGION}) + \beta_7(\text{AGE} \times \text{SEX} \times \text{REGION})\\&\quad + \beta_8(\%\ \text{TERTIARY EDUCATION}) + d_{\text{COUNTRY}} + e_{\text{COUNTRY,AGE,SEX}}\end{aligned}$$

where $d_{\text{COUNTRY}} \sim$ iid $N(0, \sigma_d^2)$ is the random-effect intercept, and $e_{\text{COUNTRY,AGE,SEX}} \sim$ iid $N(0, \sigma_d^2)$ is error.

Figure 10.7 shows a plot of the predicted estimates by actual data for 31 countries. The final model explained 52% of the within-country variance in the prevalence of physical inactivity. The remaining 48% of variance is attributed to variables not included in this model. Chile, China and the Russian Federation were identified as potential outliers and models were run including and excluding these data. The final model excluded only the Russian Federation and the predicted prevalence estimates fitted the data better by reducing the standard deviation of the residuals from 5.2 to 4.7.

Modelling was done using SAS 8.1 with the restricted maximum likelihood (REML) method and unstructured covariance structure. The REML method is a better, more conservative estimation method than least squares. We modelled within-country data as repeated measures and "countries" as a random selection of all possible countries. Various

**Figure 10.7** Plot of predicted estimates against actual data for discretionary-time physical inactivity ($n$ = 276) from 31 countries



models were compared using education and GNP with manual inclusion/exclusion of possible outlying countries. The best-fit model was assessed by minimizing the standard deviation of the residuals calculated by transforming the predicted empirical best linear unbiased predictors (EBLUPs) as well as by minimizing the –2 residual log-likelihood, Akaike's information criterion (AIC), and Schwarz's information criterion (BIC).

The model gives each country its own random-effect intercept estimate which adjusted the overall model intercepts higher or lower by a small percentage. These random-effect intercepts help the model fit the data better than a fixed-effects model by allowing each country to have a different mean value. A shortcoming in using random-effect intercepts is that the random effects are not used to adjust the intercepts for the 114 countries with no data when calculating predicted values. Therefore, the predicted values may be biased if the random-effects estimates are not randomly distributed with a mean of zero. The random-effects estimates for our model were randomly distributed within strata. Figure 10.8 presents a histogram of the distribution of the model residuals by age and sex category estimates showing a normal distribution.

Figure 10.9 shows the residuals from the final model plotted by discretionary-time physical inactivity. The plot shows an increasing trend toward positive residuals with higher estimates of physical inactivity; this is an expected effect of using skewed response data in a model that assumes normal distribution. The model underestimated high prevalence and overestimated low prevalence although the maximum absolute residual for any age-sex estimate was approximately 15%.

**Figure 10.8** Distribution of residuals from final model of discretionary-time physical inactivity ($n$ = 276)

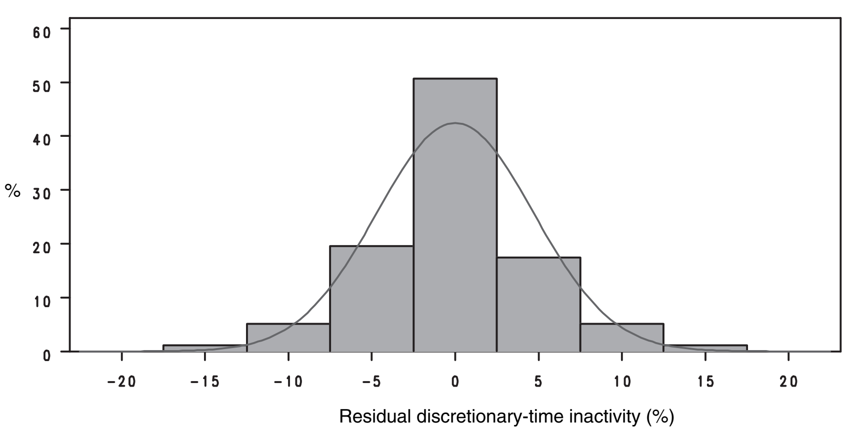


**Figure 10.9** Plot of residuals for predicted age- and sex-specific estimates of discretionary-time physical inactivity ($n$ = 276) from 31 countries

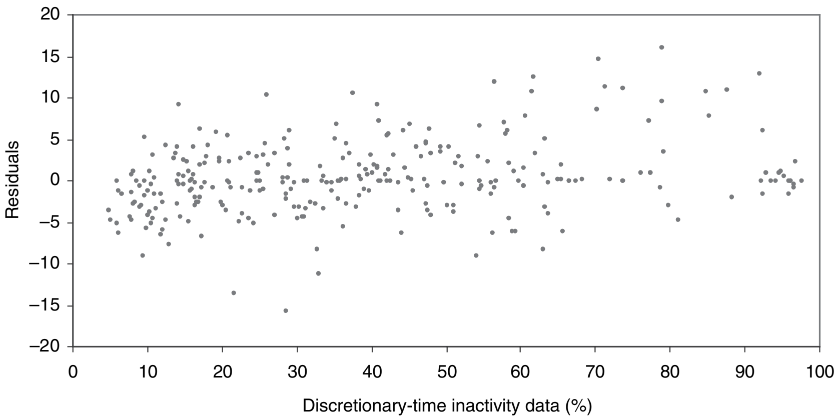



**Figure 10.10** Distribution of predicted national estimates of discretionary-time physical inactivity for all countries ($n$ = 146)

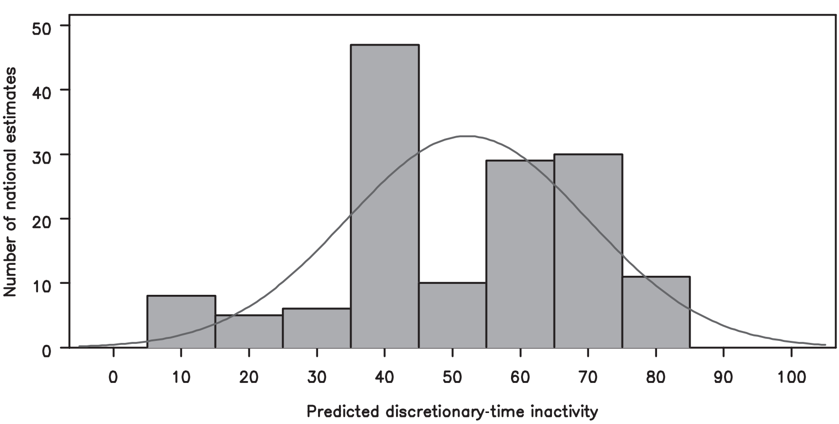
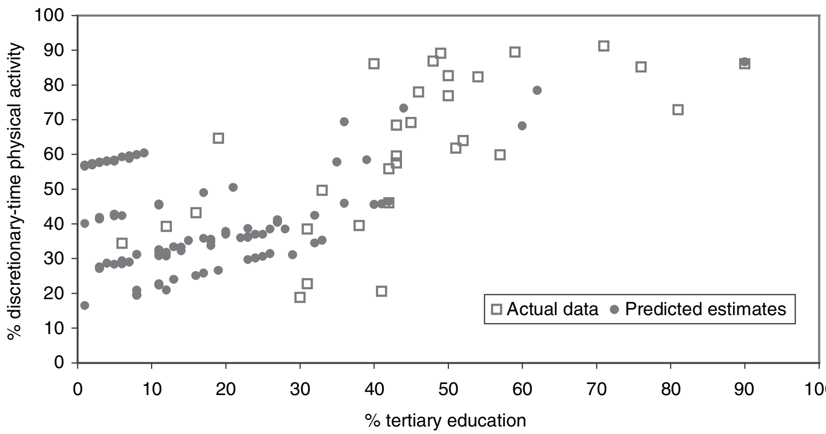



Figure 10.10 shows the distribution of predicted national estimates of discretionary-time physical inactivity from the final model for all countries (total $n$ = 146). The plot shows about one third of the countries had estimates of discretionary-time physical inactivity around 40%. Just over one third of countries had predicted estimates ranging from 55 to 75 per cent.

**Figure 10.11** Predicted national estimates of discretionary-time physical activity by the indicator % tertiary education ($n$ = 146)




The final task in this step was to convert the model output (discretionary-time physical inactivity) to estimates of physical activity. This was easily done by subtracting the values from 100. Figure 10.11 shows a plot of the predicted national estimates of discretionary-time activity for each country by the indicator % tertiary education ($n$ = 146). Countries with data are more developed with higher levels of tertiary education (shown by squares). The predicted values (circles) show different levels of activity for the same values of education reflecting the influence of our regional strata parameter in the predictive model.

*STEP 2: ESTIMATING WORK-RELATED PHYSICAL ACTIVITY*

Although several sources of data on work-related physical (in)activity were found for a number of countries (see Table 10.5), after careful inspection and discussion with the authors, few data could be included. Specifically, we found several data sets that appeared to be limited to work-related physical activity that also included some domestic activities listed as “chores”. This was true for data from Canada, Estonia, Japan, Latvia, Lithuania and the EU. Because this could inflate the prevalence estimates of work-related activity these data were excluded.

Several other countries addressed work-related activity (e.g. Egypt and Ethiopia) but these data could not be disaggregated from overall measures of physical activity. Therefore only data from China and the United States remained as distinct estimates of work-related physical activity for use in a predictive model. Fortunately these countries represent quite different societies and cultures. Moreover, because we had access to the micro data sets, age-sex estimates for both China and the United States were computed. Only estimates for heavy physical activity at work (or its equivalent) were included.

Figure 10.12 shows the proportion of adults reporting heavy activity at work by age and sex for both China and the United States. Heavy physical activity at work declines over age and is less likely to be reported by females compared with males in both China and the United States.

A simple linear regression equation was developed using the economic development indicator of % employed in agriculture (hereafter referred to as "% agriculture"). This World Bank indicator was selected and used by making the following assumptions:

- the proportion of the population employed in agriculture would reflect the level of work-related activity undertaken in a country; and
- there is a linear relationship between the proportion of the population undertaking physical activity at work and the proportion of the total population employed in agriculture.

Figure 10.13 shows the prevalence of heavy work-related physical activity by the indicator % agriculture for males and females in China and the United States. More men were active at work than women in both China and the United States but the difference was greater in the United States (absolute difference of 12% compared with 6%).

The final model parameters used to predict prevalence of work-related physical activity were % employed in agriculture (%AGR), age, sex and

**Figure 10.12** Prevalence of heavy work-related physical activity by age and sex, for China and the United States

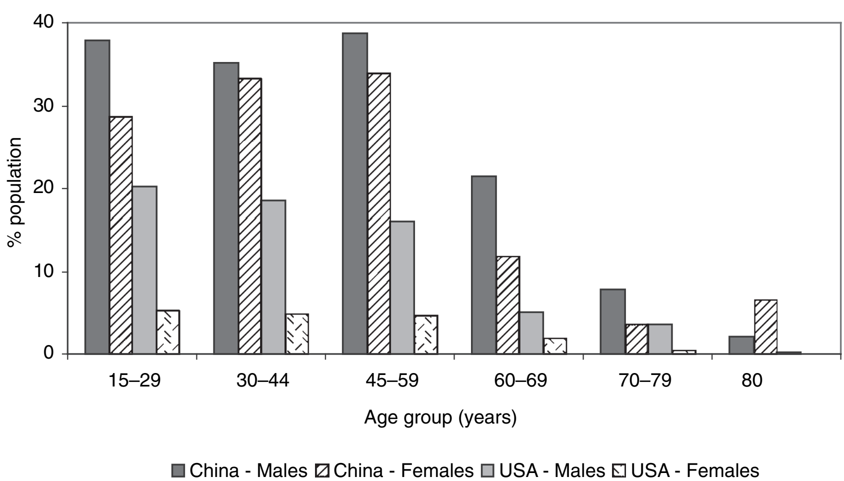
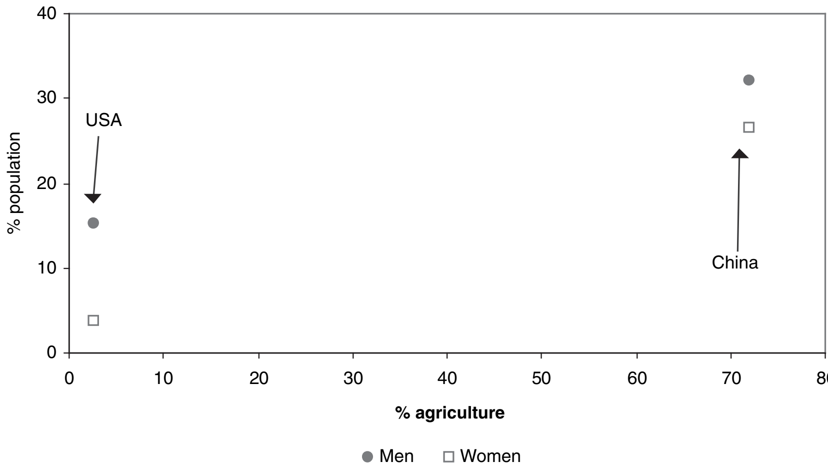


**Figure 10.13** Proportion of males and females in China and the United States who undertake heavy physical activity at work, by the indicator % agriculture

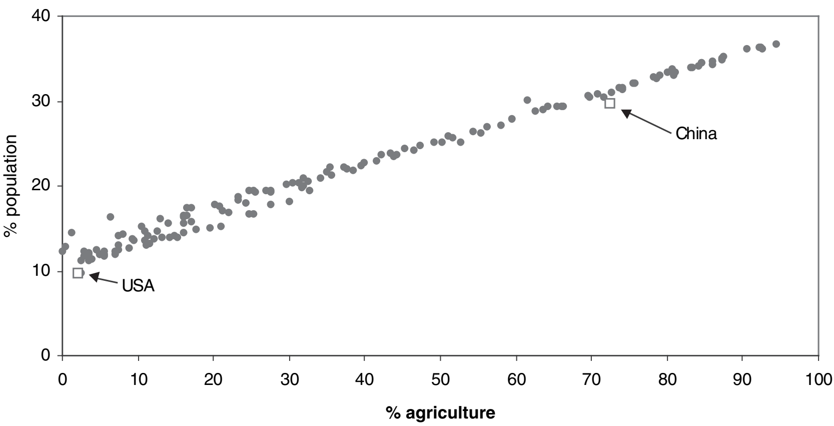



Source: China data obtained from the China Health and Nutrition Survey (Ham 2001c); United States data obtained from the NPAS (Ham 2001a) and % agriculture indicator obtained from the World Bank (1999).

an interaction term "sex by agriculture". This interaction term allowed estimates for work-related activity to vary between sex and by age as suggested by data from China and the United States (see Figure 10.12). Prevalence estimates for age categories 15–59 years were assumed to be the same because there were no clear trends by age in the data from China and the United States. However, an adjustment was introduced for age categories typically associated with retirement. Estimates for work-related activity for age categories 60–69 years, 70–79 years and ≥80 years were progressively lower than those for <60 years to account for the reduced likelihood of heavy physical work and increasing proportion of retired persons in each age group. We calculated the mean difference and reduced estimates by 13% and 19% for males and females aged 60–69 years, respectively; and by 19% and 26%, and 20% and 27% for males and females, aged 70–79 and ≥80 years, respectively (the reference estimate was 50–59 years). The magnitude of these adjustments were calculated using the mean of the differences seen between the relevant age groups in China and the United States (Figure 10.12). Additional adjustments for sex differences are described below.

Estimates for females were also adjusted to have lower values than males as suggested by the data from China and the United States (Figure

**Figure 10.14** Predicted national estimates of heavy work-related physical activity by the indicator % agriculture ($n$ = 146)




10.12) but the magnitude of difference seems to vary (range 6–12%). Thus, for the 146 countries we were working with, those countries with higher total persons employed in agriculture the difference between men and women was smallest (minimum difference set as China value namely 6%). In countries with fewer total persons employed in agriculture the difference was greatest (maximum difference set as United States value, namely 12%).

The regression equation is represented by

$$\begin{aligned} &\% \text{ heavy physical activity at work} \\ &\quad = \alpha_{\mathrm{i}} + \beta_1(\mathrm{AGE}) + \beta_2(\mathrm{SEX}) + \beta_3(\%\mathrm{AGR}) + \beta_4(\%\mathrm{AGR} \times \mathrm{SEX}) \end{aligned}$$

Figure 10.14 shows predicted national estimates of heavy physical activity at work by the indicator % agriculture.

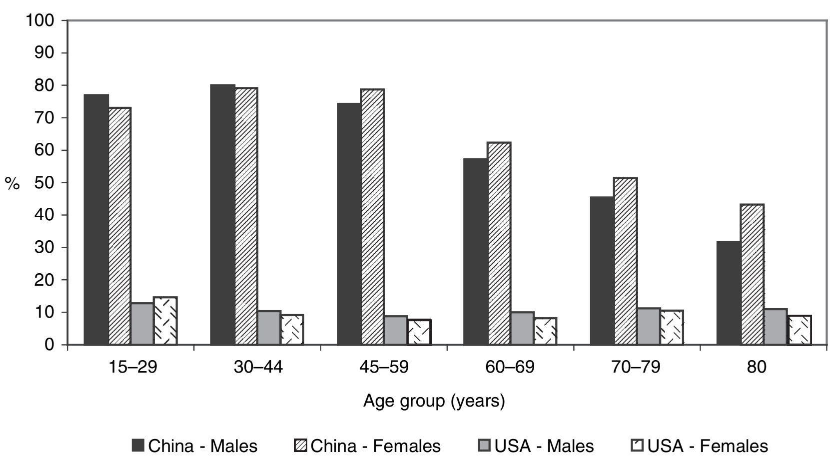
*Step 3: Estimating transport-related physical activity*

There were few data available reporting the proportion of the population undertaking transport-related physical activity, specifically cycling and walking. However some data were found reporting the per cent of "total trips" that were undertaken by bike or by foot, although even these data were not readily available from national samples.

Data used for modelling transport-related activity came from 13 countries, namely Australia (Travel Demand Management 1999), China (North Carolina Population Center 2001b), the United States (Federal Highway Administration Research and Technical Support Center 1997) and Canada and nine European countries whose data were obtained in a report comparing trends between North America and Europe (Pucher and Dijkstra 2000). Only the data from China and the United States were available with the variable "persons" rather than "trips" as the denominator. All trip data had to be converted using available information and some adjustments. We wanted to avoid assuming that a separate individual undertook each trip (e.g. 150 trips = 150 persons) because this is highly unlikely. It is more likely that a smaller proportion of the population walks or cycles and that they account for the majority of the trips (e.g. 150 trips might equal 50 persons). To explore this further we conducted new analyses using the nationwide personal transportation survey (NPTS) database (Ham 2001b) and found that 5% of all trips were cycling and walking and that they were undertaken by just 10% of the sample population. This gives a ratio of trips to persons of 1:2. This ratio was adjusted for use with data from Australia (1:1.5) and European countries (1:1.25) based on the conservative assumption that more individuals undertake more trips in these countries compared with the United States.

Figure 10.15 shows the prevalence of active transport (walk and cycle trips) undertaken by males and females in China and the United States. There was little difference between men and women in both China and the United States but considerable difference between the two countries. However, one notable difference is car ownership. This parameter was explored as a potential predictor of activity in this domain.

**Figure 10.15** Proportion of adults undertaking transport-related physical activity (cycling or walking) by age and sex, in China and the United States



A simple linear regression equation was developed using the economic development indicator of cars per thousand population (see Figure 10.16). The underlying assumption is that the prevalence of cycling and walking declines as car ownership increases.

The final regression equation is represented by

$$\text{TRANSPORT-RELATED PHYSICAL ACTIVITY} = \alpha_i + \beta_1(\text{CARS})$$
$$= \text{TRANSPORT-RELATED PHYSICAL ACTIVITY}$$
$$= 73.69 - (0.063.\text{CARS})$$

Figure 10.17 shows the predicted estimates (shown in circles) as well as actual country estimates (shown in squares) for transport-related physical activity data.

China had the lowest ownership of cars and the highest proportion of the population walking and cycling for transport. In contrast, the European countries had much higher car ownership and lower levels of active transport. Australia, Canada, New Zealand and the United States do not fit this model well. They have high estimates of car ownership, with values similar to European countries, but notably lower levels of active transport. This may be due to the degree to which these geographically large countries have developed public transportation infrastructure and the quality of these systems. It is also possible that the mean distance to work (or other destinations) is greater reflecting "sprawling" communities or particular land use patterns that may differ

**Figure 10.16** Age-sex estimates of transport-related physical activity for 13 countries, by the indicator cars per thousand population ($n$ = 156)

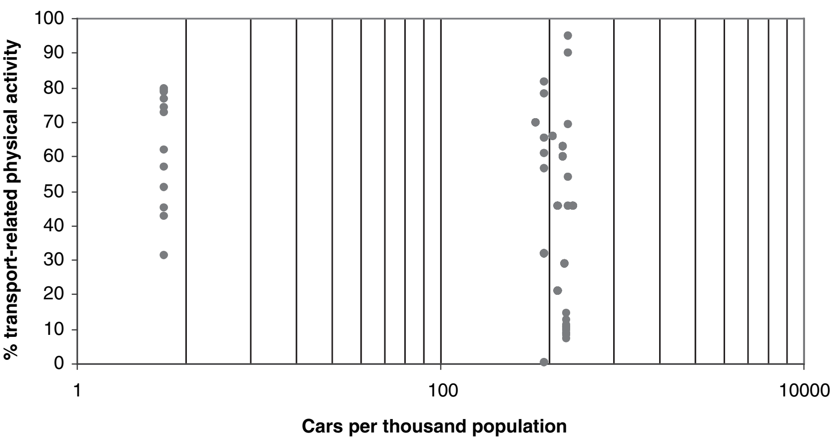
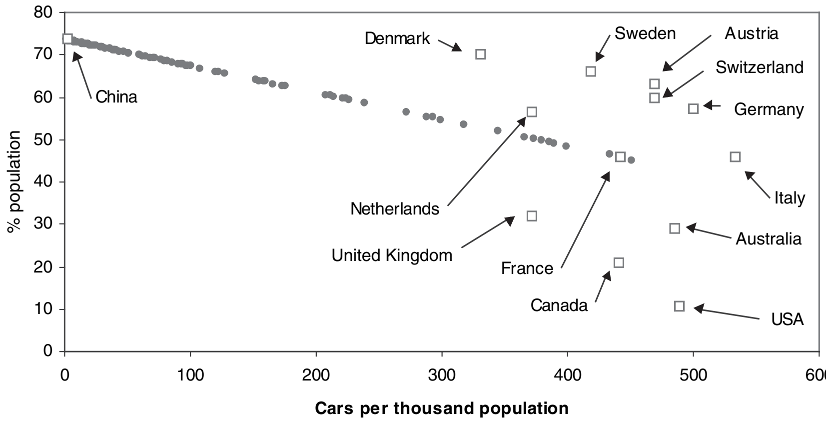


**Figure 10.17** Predicted estimates and actual country data for transport-related physical activity (cycling and walking) by the indicator cars per thousand population ($n$ = 146 countries)




between Australia, Europe and the United States. It is likely that a more sophisticated multivariate model, including average miles driven, would better describe and predict active transport. However in the absence of available data on these other possible parameters we limited our model to cars per thousand population.

Four countries had transport data by age and sex, but the pattern differed for each country (China, Germany, the Netherlands and the United States), therefore a model ignoring age and sex was developed. Australia and the United States were identified as outliers and excluded from the linear regression. In subsequent steps of the analyses the actual values for these countries, as well as from China, were used.

*STEP 4: SUMMATION OF DOMAIN ESTIMATES AND ADJUSTMENT FOR OVERLAP*

Estimates of total physical activity were obtained by combining the estimates of physical activity in each of the sub-domains (with the exception of the domestic domain). A simple summation of the estimates of activity in three domains produced country-level estimates ranging from 41% to 178% (mean 120, median 122, SD 20). High estimates of activity in more than one domain produced values well over 100%. This was anticipated because it is known that at least some individuals are active in more that one domain and a simple summation would fail to take this into account. However, the magnitude of the overlap between different domains, and for men and women, across age is not well established.

In the absence of published data we explored the pattern of activity in multiple domains using data from China and the United States (Ham

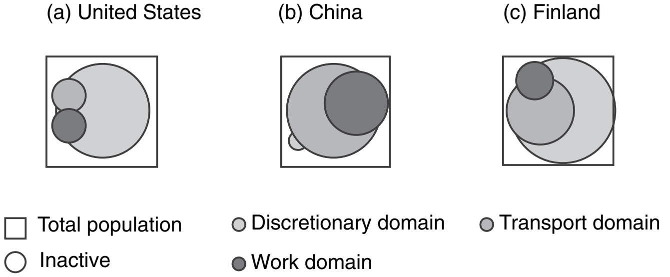
2001a, 2001b, 2001c). It was observed that 6.2% of adults in the United States were active in both work and discretionary domains, 7.1% were active in discretionary and transport domains, and 0.2% were active in both work and transport domains. These relationships are shown schematically in Figure 10.18(a).

Similar analyses were repeated with data from China and are shown in Figure 10.18(b). In China, 29% of adults were active at work and in the transport domain; 5% were active in both the discretionary and transport domains but zero per cent were active in both work and discretionary domains. Therefore the pattern of overlap is quite different compared with the United States.

Finally, data on physical activity across multiple domains were found for Finland and considered in a similar way (Luoto et al. 1998). However, without the exact data on the overlap only a hypothesized relationship between domains is shown for Finland in Figure 10.18(c). Finbalt Health Monitor data indicate that over 90% of Finnish adults are active in their discretionary time, 50% are active in transport and 13% are active at work. Accepting these values as reasonable estimates, there must be a large overlap between domains and this is shown schematically in Figure 10.18(c).

Figure 10.18 illustrates that quite different patterns of activity across different combinations of domains are possible and they are likely to vary across different countries around the world, and may vary for men and women and across age. Without additional information on these relationships it was necessary to develop a standard adjustment to our raw sum total of activity (i.e. the sum of the estimates of discretionary-time, transport-related and work-related activity), and apply this to all countries.

**Figure 10.18** Schematic representation of national data for three countries showing the proportion of activity in single and multiple domains




Source: USA: Ham (2001a); China: Ham (2001b); Finland: Finbalt data (Luoto et al. 1998).

*Adjustment of raw domain-specific estimates*

Adjustment could be made to the estimates in each of the domains ($n$ = 3) in an attempt to reduce the absolute magnitude of the prevalence estimate of total inactivity. It was also possible to consider an additional adjustment (upward) to accommodate the missing data on activity in the domestic domain. The latter was rejected because there were insufficient data to guide such an adjustment across age, sex or country. Undertaking three separate adjustments was also rejected in favour of a single adjustment and the estimate of transport-related activity was selected as our focus. Our estimate of transport-related activity was selected for the adjustment for overlapping domains for no better reason than it was judged to be the weakest data (both in quality and quantity).

With only data on physical activity across multiple domains from China and the United States (Figure 10.18 [a and b]) we were unable to identify a clear relationship, and therefore selected to reduce the raw estimate of transport-related physical activity by 60%. This gross adjustment was further refined for each country by choosing to scale the magnitude of the adjustment to a range of 50–70% based on each country's GNP. The underlying assumption was that those countries with the lowest GNP were more likely to have more active transport (cycling and walking), and therefore a smaller adjustment was appropriate (i.e. 30% reduction in absolute value of the predicted estimate). In contrast, those countries with the highest GNP were likely to have less walking and cycling so they had a larger adjustment (50% reduction in absolute value of the predicted estimate).

These functions are represented below:

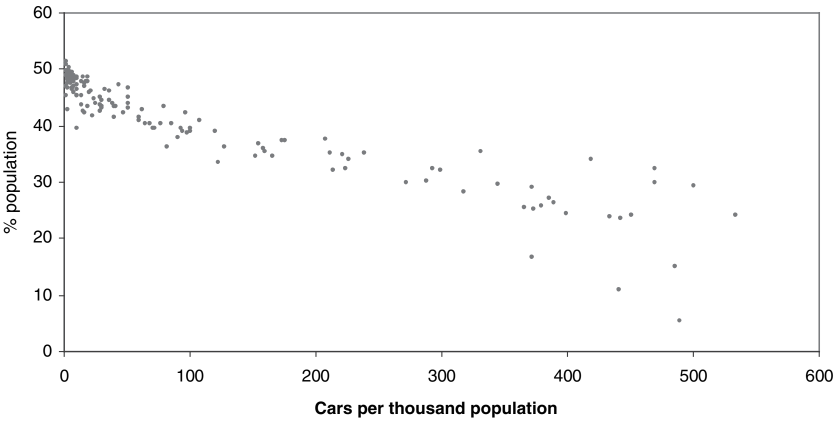
$$\text{Adjusted TRANSPORT-RELATED PHYSICAL ACTIVITY}$$
$$= \alpha_i + \beta_1(\text{CARS}) + \beta_2(\text{GNP}) + \beta_3(\text{CARS})(\text{GNP})$$
$$\text{Adjusted TRANSPORT-RELATED PHYSICAL ACTIVITY}$$
$$= (73 - 0.06\ \text{CARS})(85 - 3.35\ \text{GNP}/100)$$

Adjusted estimates for transport-related physical activity by the indicator cars per thousand population are shown in Figure 10.19 and this can be compared to the previous unadjusted data shown in Figure 10.17.

#### *Step 5: Scaling and computation of final estimates of exposure*

The age- and sex-specific estimates for discretionary-time activity, work-related activity and adjusted transport-related activity were summed to create a sum total of physical activity for each age by sex cell for each of the 146 countries. Using the adjusted transport scores, the sum totals had a range of 45–135, a mean of 95 (SD = 20.2) and median of 97. The distribution of both the adjusted and unadjusted sum totals is shown in Figure 10.20. Despite the adjustment described in Step 4, the sum total for some age by sex categories exceeded 100%. Given these values are

**Figure 10.19** Adjusted estimates for transport-related physical activity (cycling and walking) by the indicator cars per thousand ($n$ = 147 countries)



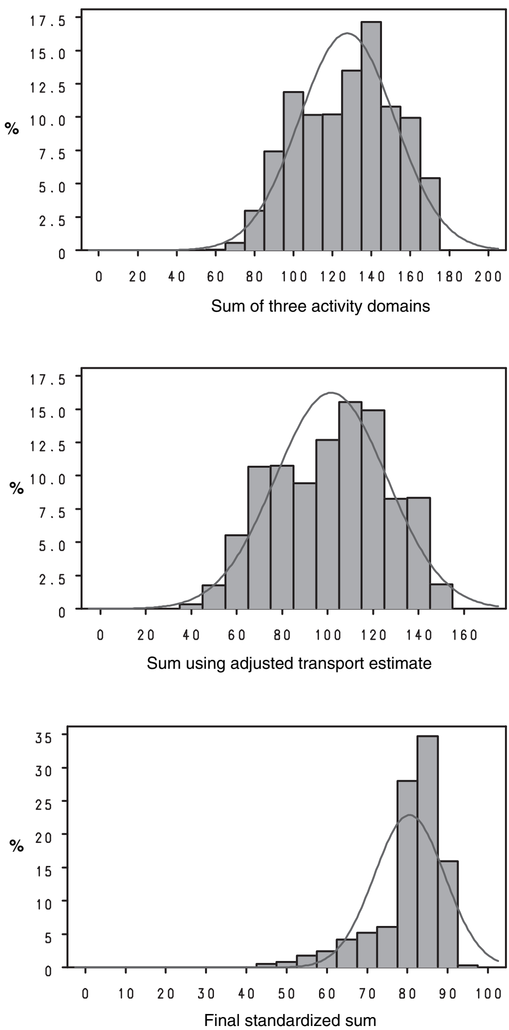

impossible some form of recalibration of at least the upper values was necessary. Scaling offered one way to address this final problem, which in itself is deemed to be primarily a result of insufficient data on levels of exposure within and between domains.

Once again, known data were used to guide this computation. Specifically, 12 age- and sex-specific estimates of total physical activity were available for both China and the United States ($n = 24$). These data were used to investigate what value to set as the mean to enable $z$-scores to be calculated and the data to be scaled. In addition, we set the maximum value for any age by sex cell for total activity as 98%. This was derived from United States data on disability that suggests approximately 2% of the whole population may not be able to achieve any physical activity in any domain. Using a maximum value of 98% and exploring various values for the mean we identified the model of best fit for the 24 age-sex category data for China and the United States. Predicted estimates of total physical activity from the best fit model are shown against actual data in Figure 10.21.

The final step was to scale the scores from Step 4 to create age x sex estimates within the range of 0–100. We calculated the $z$-scores by setting the mean at 82% and maximum at 98% and these parameters determined the SD to be 4.33. We chose to only scale estimates above the mean using the following formula:

$$\text{If TOTAL SUM SCORE} > 82 \text{ then } 82 + z\text{-score} \times \text{SD of desired distribution } (= 4.33).$$

**Figure 10.20** Distribution of estimates of total physical activity (a) before adjustment to transport, (b) after adjustment and (c) after standardizing scores above the mean




(a) Distribution of estimated prevalence scores of total physical activity for each age x sex cell before adjustment to transport-related activity

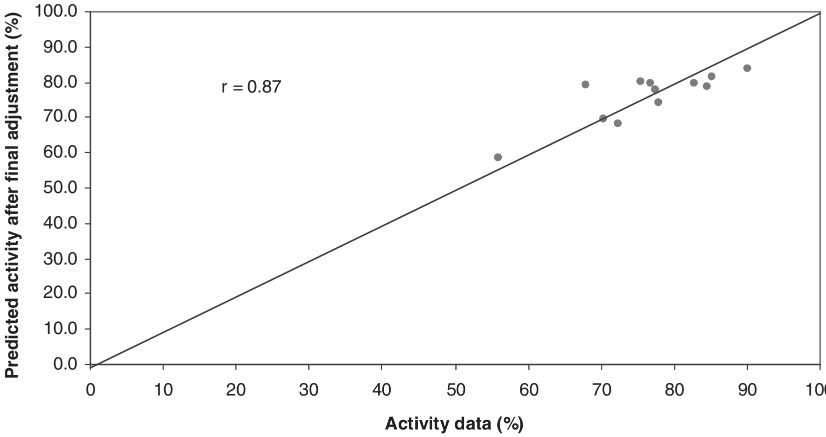
(b) Distribution of estimated prevalence scores of total physical activity for each age x sex cell after adjustment to transport-related activity

(c) Distribution of final estimated prevalence scores of total physical activity for each age x sex cell after standardization of cells with very high levels of activity

Predicted estimates that fell below 82% were not scaled. The final distribution of estimates of total activity is shown in Figure 10.20(c).

In addition to using data from China and the United States, available prevalence estimates of total physical activity (covering at least three domains) from Egypt and the United Republic of Tanzania were used to provide a check on the face validity of our final predicted estimates

**Figure 10.21** Predicted and actual age x sex estimates of total physical activity for the USA (*n* = 12)




derived from the adjusted (for activity in multiple domains i.e. Step 4) and now scaled (Step 5) model.

*Step 6: Aggregation of country estimates to create regional estimates*

The penultimate step was to create prevalence estimates in terms of the exposure variable physical inactivity by subtracting physical activity scores from 100. In order to create age- and sex-specific estimates for 14 subregions, each age by sex by country prevalence estimate was weighted to the age by sex population of the country. The final estimates for each subregion were obtained by calculating the mean level of activity for each age category for males and females. Actual data were substituted for predicted estimates where available.

Estimates of exposure to physical inactivity by subregion, sex and age are shown in Table 10.10 and graphically in Figure 10.22(a). Figure 10.22(b) depicts physical activity by domain and subregion.

## 2.8 Estimating prevalence of level 2 exposure (insufficiently active)

Consistent with our estimates of level 1 exposure, we attempted to consider all domains in our computation of level 2 exposure. We used the results of our literature search described earlier to identify those studies with data that matched or closely corresponded to our definition of level 2 exposure, those undertaking some physical activity but not sufficient amounts to meet the Centers for Disease Control and Prevention and the American College of Sports Medicine (CDC/ACSM) public health

**Table 10.10** Exposure estimates by subregion, sex and age[a]

| *Subregion* | *Sex* | *Exposure category* | *Age group (years)* 15–29 | 30–44 | 45–59 | 60–69 | 70–79 | ≥80 |
|---|---|---|---|---|---|---|---|---|
| AFR-D | Male | Inactive | 10 | 12 | 13 | 15 | 17 | 18 |
| | | Insufficient | 48 | 48 | 48 | 46 | 44 | 43 |
| | | Recommended | 42 | 40 | 40 | 39 | 39 | 39 |
| | Female | Inactive | 12 | 11 | 12 | 15 | 18 | 19 |
| | | Insufficient | 45 | 52 | 51 | 48 | 46 | 45 |
| | | Recommended | 43 | 37 | 37 | 37 | 36 | 36 |
| AFR-E | Male | Inactive | 9 | 11 | 11 | 14 | 16 | 16 |
| | | Insufficient | 50 | 51 | 50 | 49 | 47 | 46 |
| | | Recommended | 41 | 38 | 38 | 37 | 38 | 38 |
| | Female | Inactive | 11 | 10 | 10 | 13 | 15 | 15 |
| | | Insufficient | 47 | 56 | 55 | 51 | 50 | 50 |
| | | Recommended | 42 | 35 | 35 | 35 | 35 | 35 |
| AMR-A | Male | Inactive | 16 | 18 | 19 | 20 | 21 | 31 |
| | | Insufficient | 44 | 47 | 44 | 40 | 40 | 35 |
| | | Recommended | 40 | 35 | 36 | 40 | 39 | 34 |
| | Female | Inactive | 21 | 22 | 20 | 26 | 30 | 40 |
| | | Insufficient | 36 | 41 | 40 | 38 | 36 | 31 |
| | | Recommended | 43 | 37 | 40 | 37 | 34 | 29 |
| AMR-B | Male | Inactive | 16 | 17 | 18 | 22 | 25 | 28 |
| | | Insufficient | 42 | 44 | 41 | 39 | 36 | 35 |
| | | Recommended | 42 | 39 | 40 | 39 | 39 | 37 |
| | Female | Inactive | 22 | 26 | 27 | 36 | 39 | 41 |
| | | Insufficient | 33 | 32 | 31 | 30 | 30 | 29 |
| | | Recommended | 45 | 41 | 42 | 33 | 31 | 30 |
| AMR-D | Male | Inactive | 16 | 18 | 18 | 22 | 27 | 29 |
| | | Insufficient | 38 | 38 | 33 | 32 | 30 | 29 |
| | | Recommended | 46 | 45 | 49 | 46 | 43 | 42 |
| | Female | Inactive | 21 | 25 | 29 | 39 | 45 | 47 |
| | | Insufficient | 28 | 26 | 24 | 24 | 22 | 22 |
| | | Recommended | 51 | 48 | 47 | 38 | 32 | 31 |
| EMR-B | Male | Inactive | 14 | 18 | 18 | 21 | 24 | 26 |
| | | Insufficient | 41 | 39 | 38 | 36 | 32 | 32 |
| | | Recommended | 44 | 43 | 43 | 42 | 44 | 42 |
| | Female | Inactive | 18 | 20 | 20 | 24 | 30 | 32 |
| | | Insufficient | 36 | 36 | 35 | 32 | 31 | 30 |
| | | Recommended | 46 | 45 | 45 | 44 | 40 | 38 |
| EMR-D | Male | Inactive | 13 | 17 | 18 | 20 | 22 | 25 |
| | | Insufficient | 42 | 38 | 36 | 35 | 32 | 31 |
| | | Recommended | 45 | 45 | 46 | 45 | 46 | 44 |
| | Female | Inactive | 17 | 19 | 19 | 22 | 28 | 30 |
| | | Insufficient | 36 | 36 | 35 | 32 | 31 | 30 |
| | | Recommended | 47 | 45 | 46 | 45 | 41 | 39 |
| EUR-A | Male | Inactive | 13 | 15 | 16 | 18 | 20 | 21 |
| | | Insufficient | 52 | 57 | 55 | 52 | 50 | 47 |
| | | Recommended | 35 | 29 | 30 | 30 | 30 | 32 |
| | Female | Inactive | 17 | 18 | 18 | 22 | 24 | 28 |
| | | Insufficient | 47 | 51 | 51 | 45 | 45 | 42 |
| | | Recommended | 37 | 31 | 31 | 33 | 31 | 30 |

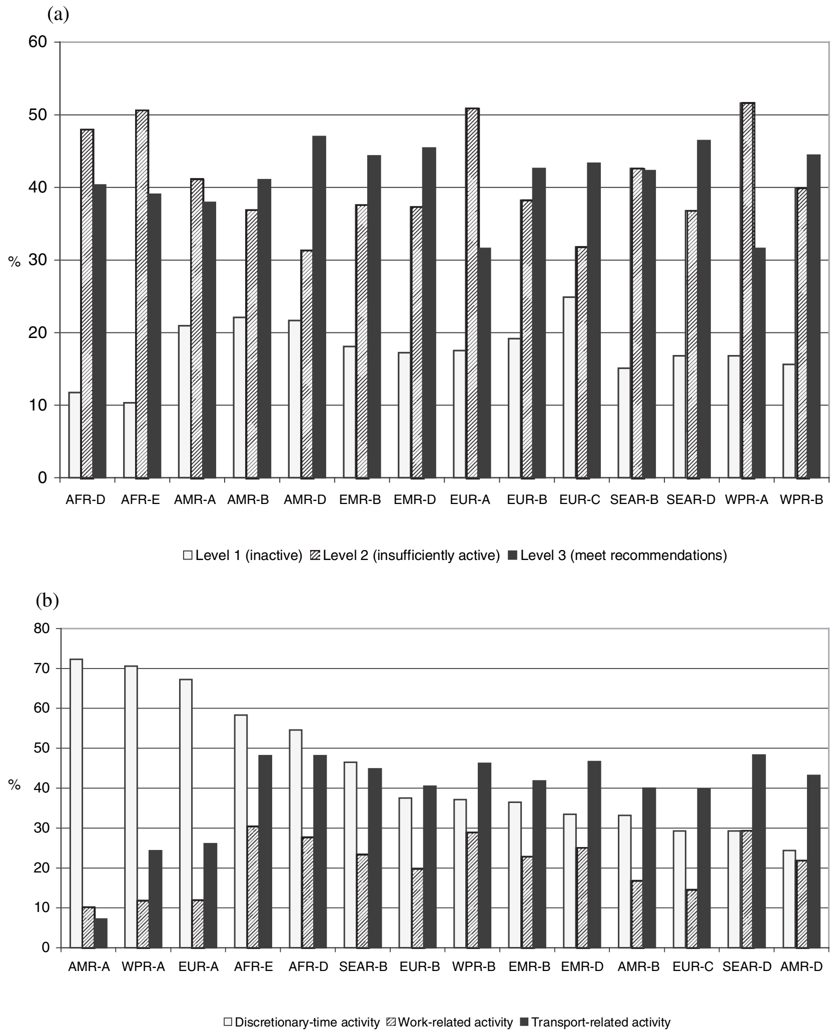
**Table 10.10** Exposure estimates by subregion, sex and age[a] (*continued*)

| *Subregion* | *Sex* | *Exposure category* | *Age group (years)* 15–29 | 30–44 | 45–59 | 60–69 | 70–79 | ≥80 |
|---|---|---|---|---|---|---|---|---|
| EUR-B | Male | Inactive | 15 | 18 | 19 | 22 | 25 | 28 |
| | | Insufficient | 43 | 40 | 38 | 36 | 34 | 33 |
| | | Recommended | 42 | 42 | 43 | 42 | 41 | 39 |
| | Female | Inactive | 18 | 20 | 21 | 26 | 31 | 32 |
| | | Insufficient | 37 | 37 | 36 | 33 | 32 | 32 |
| | | Recommended | 44 | 42 | 43 | 40 | 37 | 36 |
| EUR-C | Male | Inactive | 17 | 18 | 21 | 30 | 36 | 38 |
| | | Insufficient | 38 | 34 | 32 | 30 | 28 | 28 |
| | | Recommended | 45 | 48 | 47 | 39 | 35 | 34 |
| | Female | Inactive | 20 | 26 | 27 | 38 | 39 | 40 |
| | | Insufficient | 32 | 31 | 30 | 27 | 27 | 26 |
| | | Recommended | 48 | 43 | 43 | 34 | 34 | 34 |
| SEAR-B | Male | Inactive | 13 | 15 | 15 | 15 | 14 | 14 |
| | | Insufficient | 43 | 43 | 43 | 47 | 52 | 52 |
| | | Recommended | 44 | 42 | 42 | 38 | 34 | 34 |
| | Female | Inactive | 14 | 17 | 17 | 17 | 16 | 16 |
| | | Insufficient | 41 | 41 | 41 | 45 | 50 | 50 |
| | | Recommended | 44 | 42 | 42 | 38 | 34 | 34 |
| SEAR-D | Male | Inactive | 13 | 16 | 17 | 20 | 22 | 20 |
| | | Insufficient | 42 | 38 | 36 | 34 | 32 | 31 |
| | | Recommended | 45 | 46 | 47 | 46 | 47 | 49 |
| | Female | Inactive | 17 | 18 | 19 | 22 | 24 | 26 |
| | | Insufficient | 36 | 35 | 34 | 32 | 30 | 30 |
| | | Recommended | 47 | 47 | 47 | 47 | 46 | 44 |
| WPR-A | Male | Inactive | 14 | 15 | 16 | 18 | 17 | 17 |
| | | Insufficient | 50 | 56 | 53 | 52 | 56 | 55 |
| | | Recommended | 35 | 29 | 30 | 30 | 27 | 28 |
| | Female | Inactive | 16 | 19 | 18 | 20 | 17 | 17 |
| | | Insufficient | 48 | 49 | 50 | 49 | 55 | 54 |
| | | Recommended | 36 | 32 | 32 | 31 | 28 | 28 |
| WPR-B | Male | Inactive | 13 | 15 | 15 | 17 | 18 | 20 |
| | | Insufficient | 41 | 40 | 41 | 41 | 44 | 41 |
| | | Recommended | 46 | 44 | 45 | 41 | 38 | 38 |
| | Female | Inactive | 15 | 16 | 17 | 20 | 20 | 19 |
| | | Insufficient | 40 | 39 | 38 | 38 | 41 | 38 |
| | | Recommended | 45 | 45 | 45 | 42 | 39 | 42 |

[a] As % of total population.

recommendation of 150 minutes of moderate-intensity physical activity per week or equivalent. We found some data for the discretionary-time domain but no specific data on the level of insufficient activity in the transport- and occupation-related domains. Thus, with only a modest amount of empirical evidence we constructed a method to differentiate between those adults doing some activity but not meeting the recommended amount (i.e. level 2 exposure) and those adults meeting the current recommendations (level 3).

**Figure 10.22** Prevalence of exposure by (a) subregion and (b) prevalence of physical activity by domain and subregion

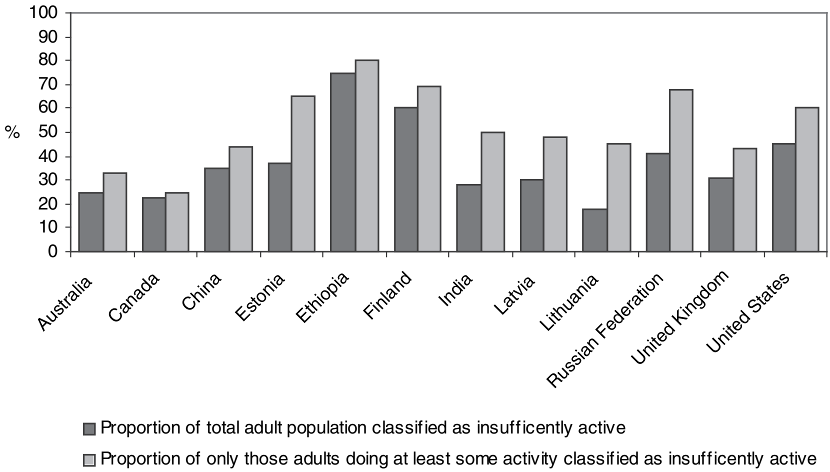



*Methods for estimating level 2 exposure by domain*

## *Discretionary-time domain*

Countries with some data on levels of insufficient activity in the discretionary-time domain were Australia, Canada, China, Estonia, Ethiopia, Finland, India, Latvia, Lithuania, the Russian Federation, the United Kingdom of Great Britain and Northern Ireland and the United States. Figure 10.23 presents the country-level estimates of % insufficient

**Figure 10.23** Prevalence of insufficiently active as a proportion of total adult population and insufficiently active as a proportion of adults who do at least some activity, in 12 countries[a]




[a] Definitions of insufficiently active are similar but not identical in each country; comparisons should therefore be made with caution.

for these 12 countries. We emphasize that these data are not exactly comparable due to different instruments and calculations as well as slightly different definitions. With the exception of Ethiopia, these data represent levels of insufficient activity in the discretionary-time domain only.

Figure 10.23 shows that there was no clear pattern across this set of countries. For instance, Canada and Australia had similar prevalence estimates of insufficiently active, namely 23% and 25% respectively, but this represented 25% of the "active" Canadian population and 33% in Australia. In contrast, 45% of the adult population in the United States was classified as insufficient and this was 63% of the active population. Finland had a very high proportion of adults doing at least some activity (90%) but of these, 63% did not meet the current recommendations. This was similar in Ethiopia. In the absence of any pattern in the proportion of adults classified as inactive with data ranging from 25–80%, we assumed that 50% of adults who were doing some activity were not active enough to meet recommendations. This rule was applied to our calculations of insufficient for all countries, male and females and all ages except the lowest age category (15–29 years). Available data indicate that younger adults are more likely to meet recommended levels of activity; therefore for this age group we assumed only 40% of those active were insufficiently active.

*Transport domain*

The data on physical activity in the transport domain are generally of poor quality. Some data from Europe suggest that approximately half of all walk and cycle trips are less than 3km. Using this information, we estimated that 50% of adults classified as active in the transport domain would be classified as insufficient because at a moderate-intensity (walking pace) 3km would take approximately 30 minutes). It is likely that trips may be longer in duration in developing countries; therefore we scaled our algorithm such that 60% of adults identified as active in countries defined as "high income" (World Bank 1999) were classified as insufficient compared with 50% and 40% of adults in "upper middle income" and the combined group of "lower middle" and "lower income", respectively. We applied no additional adjustment to account for likely age and sex differences.

*Work domain*

Data on work-related physical activity are not often reported in terms of hours of different intensity activities. Our search found few data assessing this activity in this domain alone, and only data from China were reported in hours. It is suspected that there is a large degree of measurement error in self-reporting of heavy physical activity at work; therefore some proportion of those adults reporting heavy activity may be misclassified. We decided to assume that 30% of those identified as doing heavy physical activity at work in countries defined as "high income" (World Bank 1999) did not meet recommendations. In "upper middle", "lower middle" and "lower income" countries we adjusted this assumption to 15% thus allowing more work activity "to count" as recommended. We did no further adjustments based on age or sex. Moreover, we did not attempt to estimate the proportion of adults misclassified as inactive when they should have been classified as insufficient.

*Summing across domains and final adjustment of estimates*

We used our age-sex-country estimates of level 1 exposure (inactive) within in each domain (discretionary, transport and work) to compute the prevalence of adults doing at least some activity for each age x sex x country category within each domain. This was simply 100 – % inactive. The algorithms described above were used to compute the prevalence of insufficient in each domain, which in turn were summed to derive an overall estimate for level 2 exposure.

We reviewed these data and noted the absence of any difference between males and females. In contrast, limited available data in the discretionary-time domain suggest women are less likely to be undertaking the recommended level of activity (level 3, sufficient). In addition, there is evidence of a trend over age, with older adults more likely to be insufficient compared with younger adults who are more likely to be undertaking recommended levels. We therefore developed and imposed an age and sex adjustment which resulted in the best fit between our age-sex-country estimates and available data. It was, however, not possible to get a good fit; but the results appear to reflect the regional variations even though certain individual countries may be poorly described. Computed estimates of level 2 exposure by subregion, sex and age are reported in Table 10.10.

## 2.9 Sources of uncertainty

Given the paucity of existing data in each of the domains of physical (in)activity and the complexity of the approach taken to predict estimates of exposure, there is a large degree of uncertainty around the final data. Both quantitative and qualitative approaches were taken to estimate the magnitude of this error and these steps are outlined below.

### *Methods used to estimate uncertainty and compute standard error and 95% confidence intervals*

#### *Level 1—Inactive*

Subregions were categorized according to the level of estimate uncertainty by considering both the quantity and quality of available data within each subregion. Quantity of data was assessed using the proportion of the total subregional population represented by data. Subregions with fewer data from fewer countries were deemed to have much greater uncertainty than those subregions with more data from more countries. Quality of data was assessed by considering the source of data (national or non-national samples). The subregions were classified into four levels of uncertainty.

- AFR-D, EUR-B, SEAR-B, SEAR-D — highest uncertainty;
- AFR-E, EMR-B, EMR-D — high uncertainty;
- AMR-B, AMR-D — moderate–high uncertainty;
- AMR-A, EUR-A, EUR-C, WPR-A, WPR-B — lowest uncertainty.

The predicted estimates within each domain (discretionary-time, work-related and transport-related), the missing data on domestic inactivity and the modelling procedures all represent sources of uncertainty. To account for these an adjustment factor was calculated for each age-sex-subregion estimate. The magnitude of the adjustment was proportional to the level of uncertainty surrounding the data and was a sliding scale inverse to the grading of data quality. The maximum adjustment was chosen to elicit a maximum coefficient of variation of approximately 30% for the least certain estimates. To achieve this the adjustment factor was greatest for prevalence estimates in the subregions with the highest uncertainty (25%) and smallest for those subregions with the lowest uncertainty (10%). The adjustment factor for high uncertainty and moderate–high uncertainty were 20% and 15%, respectively. The resulting uncertainty ranges for level 1 exposure are shown in Table 10.11.

The lack of data on older adults would add greater uncertainty to these estimates across all subregions. Furthermore, the omission of data (actual or predicted) on domestic-related activity may add differential levels of uncertainty to the final estimates of women compared with men and between subregions.

*Level 2—Insufficiently active*

Overall there is more uncertainty around the estimates of level 2 exposure than for level 1 due to the paucity of data and the heterogeneity among the existing data. Therefore, larger rather then smaller confidence limits were used. We computed uncertainty ranges by calculating a 25% upper and lower margin of error around each age-sex-subregion predicted estimates (Table 10.11). Given a mean level of insufficient exercise of approximately 40% this produces a range of ±10 prevalence estimate points.

## 3. Estimating physical inactivity–disease relationships

### 3.1 Selection of health outcomes

There is a large body of scientific evidence linking physical inactivity with a wide range of cardiovascular, musculoskeletal and mental health outcomes. All potential disease end-points were considered; however, for inclusion the following criteria had to be met:

1. the disease outcome is included in the Global Burden of Disease (GBD) disease list;
2. there was strong evidence for a causal association between physical inactivity and an increase in risk;
3. biologically plausible mechanisms exist to explain (at least partly) the association; and
4. sufficient information was available to allow quantification of hazard.

The disease end-points initially considered for inclusion were cardiovascular disease, specifically ischaemic heart disease and stroke, several site-specific cancers (colon, rectal, breast, prostate), type II diabetes, various musculoskeletal conditions (namely lower back pain, osteoarthritis, osteoporosis), falls and mental health outcomes (specifically depression). Literature pertaining to each of these was reviewed to

**Table 10.11** Range of uncertainty associated with estimates for level 1 and 2 exposure by subregion, sex and age

| | | | Age group (years) | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Subregion* | *Sex* | *Exposure category* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* |
| AFR-D | Male | Inactive | 4.03–15.23 | 5.18–19.38 | 5.28–19.80 | 6.58–23.70 | 7.43–27.03 | 7.54–28.86 |
| | | Insufficient | 29.31–67.10 | 29.29–67.05 | 28.93–66.23 | 28.03–64.16 | 26.60–60.90 | 26.05–59.64 |
| | Female | Inactive | 4.99–18.97 | 4.25–18.63 | 4.49–18.95 | 6.06–24.56 | 6.36–28.96 | 6.51–31.63 |
| | | Insufficient | 27.39–62.70 | 31.50–72.12 | 31.10–71.21 | 29.09–66.59 | 28.17–64.49 | 27.37–62.67 |
| AFR-E | Male | Inactive | 4.51–12.51 | 6.00–16.00 | 6.15–16.33 | 7.70–19.82 | 8.83–22.29 | 9.18–22.96 |
| | | Insufficient | 30.48–69.79 | 31.00–70.98 | 30.65–70.17 | 29.76–68.13 | 28.40–65.03 | 27.98–64.07 |
| | Female | Inactive | 5.68–15.52 | 5.04–14.36 | 5.32–14.94 | 7.37–19.59 | 8.34–21.22 | 8.73–21.97 |
| | | Insufficient | 28.79–65.91 | 33.78–77.34 | 33.17–75.94 | 31.21–71.46 | 30.51–69.85 | 30.20–69.14 |
| AMR-A | Male | Inactive | 11.93–19.95 | 12.68–23.60 | 13.12–25.70 | 14.65–25.07 | 13.91–28.25 | 20.09–41.77 |
| | | Insufficient | 26.57–60.83 | 28.46–65.16 | 26.91–61.61 | 24.45–55.99 | 24.08–55.13 | 21.50–49.22 |
| | Female | Inactive | 14.03–27.45 | 13.65–30.29 | 11.90–28.62 | 14.87–36.69 | 18.66–41.50 | 24.15–55.43 |
| | | Insufficient | 22.01–50.39 | 25.08–57.43 | 24.44–55.96 | 22.89–52.40 | 21.64–49.53 | 18.73–42.89 |
| AMR-B | Male | Inactive | 10.53–21.07 | 11.56–23.24 | 11.93–24.93 | 12.90–31.20 | 14.02–35.98 | 15.92–39.72 |
| | | Insufficient | 25.75–58.95 | 26.51–60.70 | 25.18–57.65 | 23.47–53.72 | 22.09–50.58 | 21.42–49.05 |
| | Female | Inactive | 13.88–30.84 | 15.87–37.03 | 15.25–39.17 | 21.31–51.55 | 23.32–55.40 | 24.21–57.71 |
| | | Insufficient | 19.92–45.61 | 19.56–44.78 | 18.77–42.97 | 18.50–42.35 | 18.08–41.39 | 17.56–40.20 |
| AMR-D | Male | Inactive | 10.27–21.61 | 11.48–23.92 | 11.99–24.35 | 14.16–28.84 | 15.18–39.44 | 16.02–42.68 |
| | | Insufficient | 22.92–52.48 | 22.97–52.58 | 19.95–45.66 | 19.63–44.94 | 18.13–41.52 | 17.72–40.56 |
| | Female | Inactive | 13.18–28.60 | 13.93–36.47 | 15.09–43.05 | 21.97–55.65 | 26.43–64.39 | 27.65–65.99 |
| | | Insufficient | 17.12–39.19 | 16.01–36.66 | 14.74–33.74 | 14.40–32.96 | 13.62–31.17 | 13.34–30.54 |
| EMR-B | Male | Inactive | 7.94–20.96 | 10.03–25.67 | 10.25–26.31 | 11.20–31.46 | 10.86–36.16 | 12.62–39.74 |
| | | Insufficient | 25.21–57.73 | 23.67–54.18 | 23.29–53.32 | 22.06–50.50 | 19.70–45.11 | 19.19–43.95 |
| | Female | Inactive | 10.23–25.95 | 11.13–28.27 | 11.19–28.83 | 10.85–36.77 | 15.37–44.09 | 17.05–47.09 |
| | | Insufficient | 21.88–50.10 | 21.67–49.62 | 21.31–48.79 | 19.43–44.49 | 18.69–42.79 | 18.30–41.90 |
| EMR-D | Male | Inactive | 6.78–20.18 | 8.65–25.27 | 9.01–26.43 | 10.54–30.06 | 10.94–33.36 | 12.29–39.74 |
| | | Insufficient | 25.29–57.91 | 23.22–53.17 | 22.15–50.71 | 20.98–48.04 | 19.48–44.60 | 18.89–43.24 |
| | Female | Inactive | 8.60–25.74 | 8.91–28.51 | 9.12–28.94 | 10.62–34.06 | 13.35–43.65 | 13.87–46.59 |
| | | Insufficient | 21.94–50.24 | 21.90–50.15 | 21.47–49.16 | 19.62–44.92 | 18.81–43.05 | 18.53–42.41 |

*continued*

**Table 10.11** Range of uncertainty associated with estimates for level 1 and 2 exposure by subregion, sex and age (*continued*)

| | | | *Age group (years)* | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Subregion* | *Sex* | *Exposure category* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* |
| EUR-A | Male | Inactive | 10.02–16.76 | 10.81–18.47 | 11.32–19.76 | 13.07–22.85 | 13.72–25.62 | 14.99–27.41 |
| | | Insufficient | 31.56–72.25 | 34.57–79.14 | 33.33–76.31 | 31.82–72.85 | 30.61–70.08 | 28.68–65.65 |
| | Female | Inactive | 12.19–21.05 | 12.97–22.65 | 13.02–23.28 | 15.29–29.63 | 16.08–31.66 | 18.39–36.95 |
| | | Insufficient | 28.39–65.00 | 31.17–71.37 | 30.84–70.62 | 27.25–62.39 | 27.19–62.26 | 25.82–59.11 |
| EUR-B | Male | Inactive | 6.69–21.85 | 8.40–27.00 | 8.92–28.38 | 10.11–31.75 | 10.84–38.98 | 11.87–43.05 |
| | | Insufficient | 26.17–59.92 | 24.49–56.07 | 23.30–53.36 | 22.09–50.57 | 20.59–47.15 | 20.16–46.16 |
| | Female | Inactive | 8.58–27.62 | 9.47–30.11 | 9.80–30.92 | 11.15–40.51 | 12.82–48.68 | 13.36–50.64 |
| | | Insufficient | 22.77–52.14 | 22.73–52.04 | 22.15–50.72 | 20.32–46.52 | 19.59–44.85 | 19.32–44.24 |
| EUR-C | Male | Inactive | 11.50–21.54 | 13.51–22.49 | 14.88–27.98 | 18.45–42.51 | 21.16–51.62 | 21.64–54.24 |
| | | Insufficient | 23.11–52.92 | 20.64–47.26 | 19.38–44.36 | 18.34–41.98 | 17.22–39.43 | 16.94–38.78 |
| | Female | Inactive | 14.39–25.89 | 16.90–36.06 | 17.02–37.08 | 22.04–54.54 | 21.33–56.49 | 22.26–57.94 |
| | | Insufficient | 19.34–44.29 | 18.78–42.99 | 18.43–42.19 | 16.62–38.05 | 16.27–37.25 | 15.91–36.42 |
| SEAR-B | Male | Inactive | 5.73–20.03 | 6.82–23.70 | 6.83–23.71 | 7.02–23.90 | 6.40–21.78 | 6.59–22.31 |
| | | Insufficient | 26.18–59.93 | 25.96–59.44 | 25.95–59.41 | 28.47–65.18 | 31.73–72.65 | 31.57–72.29 |
| | Female | Inactive | 6.41–22.57 | 7.60–26.52 | 7.53–26.29 | 7.73–26.43 | 7.09–24.25 | 7.28–24.72 |
| | | Insufficient | 25.22–57.74 | 24.63–56.38 | 24.85–56.89 | 27.39–62.71 | 30.70–70.28 | 30.56–69.96 |
| SEAR-D | Male | Inactive | 6.34–19.36 | 8.17–24.73 | 8.49–25.95 | 9.50–30.38 | 9.57–33.43 | 9.46–30.96 |
| | | Insufficient | 25.38–58.10 | 22.96–52.56 | 21.87–50.07 | 20.81–47.64 | 19.33–44.24 | 18.88–43.23 |
| | Female | Inactive | 8.11–24.91 | 9.10–27.58 | 9.23–28.03 | 10.11–33.21 | 10.94–36.94 | 11.50–41.28 |
| | | Insufficient | 21.94–50.23 | 21.26–48.67 | 20.84–47.72 | 19.17–43.89 | 18.38–42.08 | 18.02–41.25 |
| WPR-A | Male | Inactive | 10.31–18.25 | 11.15–19.07 | 12.05–20.37 | 13.65–21.97 | 12.86–20.80 | 12.61–21.35 |
| | | Insufficient | 30.60–70.06 | 34.00–77.84 | 32.46–74.33 | 31.79–72.79 | 33.91–77.65 | 33.70–77.16 |
| | Female | Inactive | 11.72–20.60 | 13.40–24.08 | 13.36–23.00 | 15.30–23.84 | 12.98–21.36 | 12.49–22.29 |
| | | Insufficient | 28.93–66.24 | 29.80–68.22 | 30.59–70.03 | 30.06–68.81 | 33.44–76.55 | 33.13–75.85 |
| WPR-B | Male | Inactive | 10.07–16.44 | 11.91–18.93 | 11.53–18.07 | 13.22–21.62 | 13.51–23.27 | 14.49–26.19 |
| | | Insufficient | 24.93–57.07 | 24.39–55.83 | 24.65–56.44 | 25.13–57.53 | 26.55–60.79 | 25.14–57.56 |
| | Female | Inactive | 11.28–18.34 | 12.76–19.90 | 13.08–20.58 | 15.09–25.27 | 14.88–25.98 | 14.42–24.56 |
| | | Insufficient | 24.30–55.64 | 23.64–54.13 | 23.05–52.77 | 23.19–53.09 | 24.83–56.85 | 23.14–52.99 |

**Table 10.12** Health outcomes considered in this analysis

| *Health outcome* | *GBD classification system outcome* | *Causal* | *Biological plausibility* | *Risk data* | *Inclusion/Exclusion* |
|---|---|---|---|---|---|
| Ischaemic heart disease | Yes | Yes | Yes | Yes | Included |
| Stroke | Yes | Yes[a] | Yes[a] | Yes | Included[a] |
| Type II diabetes | Yes | Yes | Yes | Yes | Included |
| Breast cancer | Yes | Yes | Yes | Yes | Included |
| Colon cancer | Yes | Yes | Yes | Yes | Included |
| Prostate cancer | Yes | Uncertain | Uncertain | Limited | Excluded |
| Rectal cancer | Yes | Uncertain | Uncertain | Limited | Excluded |
| Low back pain | Yes | Some | Some | Limited | Excluded |
| Osteoporosis | No | Some | Some | Limited | Excluded |
| Osteoarthritis | No | No | No | Limited | Excluded |
| Falls | No | Some | No | Limited | Excluded |
| Depression | Yes | No | Uncertain | Limited | Excluded |
| Obesity | No | Yes | Yes | No | Excluded |

[a] For ischaemic stroke only.

identify the level of evidence on causality. For several outcomes there is a considerable level of interest and a large number of studies, particularly in recent years, but insufficient support for the biological mechanism associated with physical inactivity. In these cases the disease outcomes were excluded but any future attempts at assessing attributable burden should update our review. Below is a brief summary of the evidence and proposed biological mechanisms associated with physical inactivity for each disease end-point considered. These are summarized in Table 10.12.

### *Cardiovascular diseases*

#### *Ischaemic heart disease*

The strongest evidence for the benefits of physical activity pertains to the reduction of risk of mortality and morbidity from cardiovascular disease, particularly acute myocardial infarction and other forms of ischaemic heart disease (Berlin and Colditz 1990; Powell et al. 1987). These associations are generally strong and independent of the definition of physical activity used. Biologically plausible mechanisms for the effects of moderate and/or vigorous intensity physical activity on ischaemic heart disease have been identified through clinical and observational studies. The mechanisms or pathways include advantageous effects on atherosclerosis, lipid profile, ischaemia, blood pressure, thrombosis and fibrinolytic activity (Hardman and Stensel 2003).

A number of studies have shown physical activity directly and indirectly reduces the effects of excess cholesterol and other atherosclerotic agents (Durstine and Haskell 1994; Kramsch et al. 1981; Leon 1991). Participation in physical activity can improve total blood cholesterol levels (McMurray et al. 1998) and improve high density lipoprotein (HDL) subfraction profiles (Moore 1994). An increase in HDL is desirable because HDL transports cholesterol to the liver for elimination in the bile, and thus has an "anti-atherosclerotic" function. Physical activity has also been shown to increase the activity of lipoprotein lipase, which is involved in the removal of cholesterol from the blood (Stefanick and Wood 1994). There may be, however, a threshold for the relationship between physical activity and improvements in the HDL subfraction of cholesterol, with prolonged or intensive physical activity being more beneficial for HDL to cholesterol ratios (Kokkinos and Fernhall 1999).

Decreased risk of ischaemia may be due to positive adaptations in coronary circulation from structural adaptations following physical activity (Laughlin 1994; Tomanek 1994). Acute coronary events may be reduced by a reduction in thromboses by an increase in enzymatic (fibrinolytic) breakdown of blood clots and a decrease in platelet aggregation (Leon 1991).

Vigorous physical activity has been shown to decrease systolic and diastolic blood pressures (Arroll and Beaglehole 1992; Kelley and McClellan 1994; McMurray et al. 1998; Mensink et al. 1999). Moreover there is some evidence that participation in more moderate-intensity activity may achieve similar or even greater effects than vigorous activity (Hagberg et al. 1989; Marceau et al. 1993; Matsusaki et al. 1992; Moreau et al. 2001). The proposed mechanisms by which blood pressure is lowered is via the immediate and temporary dilation of the peripheral blood vessels during physical activity and the ongoing effect of a reduction in sympathetic nervous system activity (Fagard and Tipton 1994).

### *Stroke*

A recent review of the dose–response relationship between physical activity and risk of stroke suggests current evidence remains equivocal (Kohl 2001). Only six studies from a total of 15 showed evidence of a dose–reponse relationship; eight did not and two studies suggested a "U" shaped distribution (Kohl 2001). While this presents an unclear picture, it is notable that many studies did not differentiate between the two different types of stroke: ischaemic and haemorrhagic, as we describe in detail below.

The biological mechanisms for the association between physical activity and ischaemic stroke and ischaemic heart disease are thought to be similar, namely atherosclerosis and hypertensive disease (Kohl 2001). However, the biological pathway for haemorrhagic stroke is less clear. Given potentially different pathophysiological pathways, it follows that physical activity may be differentially related to one type (ischaemic) and not the other (haemorrhagic). In general, studies show a decrease in the risk of ischaemic stroke with increasing levels of physical activity (Ellekjaer et al. 2000; Wannamethee and Shaper 1999) but studies with separate risk by sub-type show no or smaller associations with varying levels of activity for haemorrhagic stroke (Hu et al. 2000).

Given the evidence is mixed for an association between overall stroke and physical inactivity and sufficient evidence on causality and burden exists only for ischaemic stroke, for this study, only ischaemic stroke was included.

*Type II diabetes*

A recent review (Ivy et al. 1999) showed that the benefits of physical activity in the prevention of type II diabetes are strongly supported by current research, especially among people already at risk (Kelley and Goodpaster 2001). In general, prospective observational studies show a lower incidence of type II diabetes in more active people compared with the least active in the population. Both moderate- and vigorous-intensity physical activity reduce the risk of type II diabetes in women (Hu et al. 1999), and the benefits appear to accrue also for males and in diverse populations (Folsom et al. 2000; Okada et al. 2000). Reduction in risk of type II diabetes appears to occur only from regular, sustained physical activity.

The biological mechanisms for this protection have not been clearly identified, but are likely to occur at systemic, tissue and cellular levels. Numerous studies and reviews have described either a short- and/or a long-term effect from participation in physical activity on glucose tolerance and carbohydrate metabolism. In general, physical activity increases sensitivity to insulin, improves glucose metabolism, reduces atherosclerosis risk, and reduces intra-abdominal fat distribution (Kelley and Goodpaster 2001). Physical inactivity appears to relate to increased risk of type II diabetes by two possible pathways, which are described in detail by Katzmarzyk et al. (1996). Briefly, one pathway involves the relationship between physical inactivity, a positive energy balance, and an increase in adiposity. The resulting insulin resistance leads to a reduction in plasma free fatty acid (FFA) clearance. Elevated blood FFA levels have detrimental effects on blood glucose, which result in increased pancreatic $\beta$ cell insulin secretion and hyperinsulinaemia in order to control blood glucose levels. The increased requirement for insulin causes $\beta$ cell impairment and reduced blood insulin levels, which increases the insulin resistant state, further reduces clearance of FFA from the blood, increases glucose levels and results in type II diabetes (Katzmarzyk et al. 1996).

A second mechanism suggests that a physically inactive lifestyle exposes a genetic predisposition in skeletal muscle, which can result in muscular insulin resistance. This results in increases in $\beta$ cell insulin secretion and hyperinsulinaemia to control blood glucose concentrations. One result of hyperinsulinaemia is a suppression of fatty acid oxidation and increases of triglyceride storage, and adipose cell hypertrophy. Adipose cells then become insulin resistant and there is a reduced ability to remove FFA from the blood. This results in an increase in glucose output from the liver and further development of muscle insulin resistance. Ultimately, the increased reliance on insulin to control blood glucose concentration results in $\beta$ cell impairment and development of type II diabetes.

The physiological adaptations that are responsible for the protective effects of physical activity subside within a short period of the cessation of physical activity, within two weeks of inactivity (Arciero et al. 1999; Dela et al. 1993; Rogers et al. 1990). Therefore physical activity must be undertaken regularly to provide benefits in terms of risk reduction.

The evidence for a causative association between physical inactivity and increased risk of type II diabetes was strong enough for inclusion.

### *Cancers*

#### *Colon cancer*

Numerous studies have shown the protective effect of physical activity on risk of colon cancer (Colditz et al. 1997; IARC 2002; Thune and Furberg 2001) and on the prevention of precancerous polyps in the large bowel (Neugut et al. 1996; Slattery et al. 1997). However, no definitive biological mechanisms have been identified to explain the relationship between physical inactivity and increased risk of colon cancer although several mechanisms have been proposed, which link physical activity and changes in physiologic measures.

One possible mechanism is the effect of prostaglandins on colon mucosal cell proliferation. Physical activity produces an increase in prostaglandin F2 alpha that increases intestinal motility, and a decrease in prostaglandin E2, which stimulates colon cell proliferation (Thor et al. 1985; Tutton and Barkla 1980). Further support for this possible mechanism comes from laboratory studies on rats and evidence in humans that aspirin and nonsteroidal anti-inflammatory drugs, also inhibitors of prostaglandin synthesis, reduce risk of colon cancer (Tomeo et al. 1999). A second mechanism relates physical inactivity and abdominal obesity and proposes that obesity may increase the risk of colon cancer via its influence on insulin-like growth factor-1 (IGF-1) and insulin-like growth factor binding proteins (IGFBP). Since insulin is a growth factor for colon mucosal cells this may promote cancerous cell production. Thus, it is possible that activity exerts its protective effect through reduced insulin levels, because physical activity has been shown to reduce insulin levels in both obese individuals and those of healthy weight (Giovannucci et al. 1995; McKeown-Eyssen 1994; Tomeo et al. 1999). Insulin-like growth factor is associated with colon cancer risk (Giovannucci et al. 2000; Ma et al. 1999), and IGF is influenced by caloric intake and physical activity. Thus higher levels of physical activity may down-regulate IGF by increasing the production of the binding protein (IGFBP3). The nature of the evidence for an association between physical inactivity and colon cancer was sufficient to meet criteria for inclusion.

*Rectal cancer*

There is less evidence for a significant causal association between physical inactivity and rectal (or colorectal) cancer. A recent review of studies in which separate risk estimates for colon and rectal cancers were provided found no association between physical activity and rectal cancer in 80% of studies included in their review (Thune and Furberg 2001). The authors suggest that the apparent protective effect of physical activity on colorectal cancer may be derived, in the main, from the association between physical activity and colon cancer (Thune and Furberg 2001). On the basis of this review rectal (or colorectal) cancer was not included in this study.

*Breast cancer*

The majority of studies investigating the benefits of physical activity and breast cancer report a reduction in the risk of breast cancer among physically active women (Gammon et al. 1998; Latikka et al. 1998; Verloop et al. 2000). There is substantial evidence that discretionary-time and/or occupational physical activity is associated with approximately a 30% reduction in the risk of breast cancer in pre-, peri- and post-menopausal women (Thune and Furberg 2001). Increased number of lifetime ovulatory cycles and cyclic estrogen has been proposed as a risk factor for breast cancer (Henderson et al. 1985). The impact of regular physical activity on the secretion, metabolism, and excretion of the sex hormones estradiol and progesterone provides a biologically plausible causal mechanism for the reduction of risk for breast cancer among physically active women. However, elevated relative and absolute estrogen levels may increase the risk of breast cancer (McTiernan et al. 1996). The strength and nature of the evidence for an association between physical inactivity and risk of breast cancer meets criteria for inclusion.

*Prostate cancer*

There is limited evidence showing vigorous activity may provide a protective effect against prostate cancer in men (Giovannucci et al. 1998) and other researchers have not found such a relationship (Liu et al. 2000). A recent review of 24 studies found that 14 suggested an inverse association of physical activity on prostate cancer, six showed no association, and an increased risk of prostate cancer was observed among the most physically active men in four other studies (Friedenreich and Thune 2001). Given these equivocal results prostate cancer was not included in this project.

#### *Musculoskeletal conditions*

Participation in physical activity throughout the course of life can increase, maintain or reduce the decline of musculoskeletal health that generally occurs with ageing in sedentary people (Brill et al. 2000). Participation by older adults can help maintain strength and flexibility, resulting in an ability to continue to perform daily activities (Brill et al. 2000; Huang et al. 1998; Simonsick et al. 1993). Furthermore, participation can reduce the risk of falling and hip fractures in older adults. (Grisso et al. 1997; Lord 1995) Evidence for associations between physical inactivity and low back pain, osteoporosis and falls, and oesteoarthritis are examined below.

##### *Low back pain*

Low back pain is a term applied to a group of conditions or symptoms where there is pain, muscle tension and/or stiffness in the lower back. Low back pain may or may not include sciatica and other "nerve" discomfort. Physical activity is associated with both increased and decreased risk for low back pain. Certain specific activities such as heavy physical work, lifting, twisting, pulling, pushing that generally occur in occupational or during some specific discretionary-time activities (e.g. certain sports, heavy yard work) can increase the risk of low back pain (Picavet and Schouten 2000; Vuori 2001). However, participation in certain types of exercise may also reduce risk of low back pain. Four potential mechanisms for the protective effects of specific types of physical activities were proposed by Suni (2000), namely: increased abdominal and back muscle strength; better mobility and flexibility of trunk; increased endurance of trunk muscles assisting in the maintenance of motor control and stability; and increased capacity for appropriate motor skills.

Although there is some evidence from randomized controlled trials to show that low back pain can be prevented by participation in specific exercises, the evidence on participation in general physical activity and reduction on risk of low back pain is neither consistent nor strong (Vuori 2001). The outcomes are often poorly defined in many studies and this is in part due to the problematic nature of the term "low back pain", which is used for a collection of conditions with various International Statistical Classification of Diseases and Related Health Problems, tenth revision (ICD-10) codes (M45–48). Further, the type of physical activity associated with a reduced risk of low back pain has yet to be fully elucidated. Since participation in specific types of activity can not be identified at a population level there is insufficient information on which to quantify hazard. Low back pain therefore was not included as a health outcome in this project.

*Osteoporosis and falls*

Osteoporosis is characterized by low bone mass and structural deterioration of bone tissue leading to bone fragility and increased risk of fractures. The development of osteoporosis has been shown to be associated with physical inactivity (Drinkwater 1994). The biological mechanism proposed for the benefits of physical activity is via the impact on bone density. Put simply, bone cells respond to mechanical loading by increasing bone mass through improvements between bone formation and bone resorption (Lanyon 1993) and this process is mediated by glucose-6-phosphate, prostaglandins and nitric oxide (Pitsillides et al. 1995; Tang et al. 1995; Turner et al. 1995). Cross-sectional studies show that participation in weight-bearing physical activity is positively associated with bone density (Gutin and Kasper 1992). Undertaking weight-bearing activity is particularly important in the development of peak bone density for adolescents (Welten et al. 1994) and for middle-aged women (Zhang et al. 1992).

Although this mechanism is strongly supported by the American College of Sports Medicine (ACSM), their position statement on osteoporosis states the types of activity most effecting such change are still not clear (1995). A recent review came to similar conclusions (Vuori 2001).

Systematic reviews of the literature have identified the beneficial role of physical activity in reducing the risks of falls in the elderly (Gillespie and McMurdo 1998; Kujala et al. 2000). Participation in physical activity is likely to be beneficial through an increase in bone strength, muscle strength, balance and coordination (Gregg et al. 2000). Currently osteoporosis is not listed as an outcome in the GBD classification system for diseases and injuries, but rather is grouped with "other musculoskeletal conditions". Given we were unable to classify what proportion of other musculoskeletal conditions are attributable to osteoporosis, or quantify the proportion of osteoporosis attributable to physical inactivity, falls were excluded from this project. Excluding osteoporosis and falls is based upon application of the specific criteria of this report, and does not indicate that physical activity is not important in fall prevention, or that there is not evidence suggesting a causal relationship.

*Osteoarthritis*

Physical activity appears to be beneficial for controlling the symptoms of osteoarthritis and maintaining the health of joints. However there is limited evidence that physical activity itself can prevent osteoarthritis.

Conversely, there is evidence that certain types of physical activity, such as sustained participation in training and competition in elite sports, can lead to injuries and may increase the risk of osteoarthritis (Kujala et al. 1994, 1995; U.S. Department of Health and Human Services 1996). However, these studies are often based on extremely small samples and specific populations and this limits their generalization to whole populations. Moreover, participation in recreational running, as opposed to competitive athletics, over a long period was not shown to increase risk of osteoarthritis (Lane 1995). Due to a lack of evidence for a causal association, and the absence of clear biologically plausible mechanisms, osteoarthritis was excluded from this review.

#### *Depression*

Observational studies demonstrate that participation in discretionary-time and/or occupational physical activity can reduce symptoms of depression and possibly stress and anxiety (Dunn et al. 2001; Glenister 1996; Hassmen et al. 2000; Paffenbarger et al. 1994). Physical activity may also confer other psychological and social benefits that impact on health. For example, participation by individuals can help build self-esteem (Sonstroem 1984), social skills among children (Evans and Roberts 1987), positive self-image among women (Maxwell and Tucker 1992) and improve quality of life among children and adults (Hassmen et al. 2000; Laforge et al. 1999; Morans and Mohai 1991). These benefits are probably due to a combination of participation in the activity itself and from the social and cultural aspects that can accompany physical activity.

However, interpretation of the evidence on how physical activity might improve mental health is difficult due to less than ideal methodology and inconsistencies in study designs. Often studies involve small samples and use different definitions and measures of mental health outcomes. Thus, although the literature supports a beneficial effect on relieving symptoms of depression and anxiety, and as a treatment modality, there is currently limited evidence that physical activity can reduce the risk of depression and no clear evidence for a causal association. Exclusion of depression does not indicate that physical activity is not considered important for mental health; it indicates rather that the current evidence does not provide sufficient information for compliance with the inclusion criteria for this project.

#### *Obesity*

There is considerable interest in the role of physical activity on weight. The available literature comprises a large body of observational studies showing that habitual physical activity over a lifetime can attenuate the increase in weight normally associated with increasing age, and participation in appropriate amounts of activity can lead to weight maintenance, or even weight loss (Grundy et al. 1999). The latter is especially true if physical activity is combined with a restriction of dietary energy intake. There are several proposed biological mechanisms for the association between physical inactivity and obesity (Hill and Melanson

1999). The most simple being that obesity occurs when energy intake (dietary intake) exceeds total energy expenditure (including the contribution of physical activity).

In this book, obesity is assessed as a risk factor (see Chapter 8). Moreover, it is currently not listed as a condition in the GBD classification system, instead it is included within the group "endocrine disorders". For these reasons obesity did not meet our inclusion criteria. Like depression, osteoporosis and other excluded disease end-points, exclusion does not imply the lack of any identified association with physical activity nor any lack of importance. Indeed, for obesity there is an urgent need for research and public health interventions to control and reverse the epidemic. Many health outcomes mediated through obesity are also among those considered above.

### 3.2 Search strategies for data sources

Medline and manual searches were conducted to identify review articles, individual studies and published meta-analyses of studies on the relationship between physical activity and the selected disease outcomes. The search was limited to studies published in English from 1980 to 2001. Keywords used were *physical activity* or *exercise*, along with at least one of the relevant disease outcomes listed below.

#### *Coronary heart disease OR cardiovascular disease*

Overall our search identified a total of seven quantitative or qualitative reviews on the relationship between physical activity and ischaemic heart disease. These were: a qualitative review by Powell et al. (1987); a quantitative replication of Powell et al. by Berlin and Colditz (1990); a qualitative review undertaken as part of the 1996 U.S. Surgeon General's report on physical activity and health (U.S. Department of Health and Human Services 1996); a quantitative meta-analysis of 12 cohort studies by Eaton in 1992; a review of the dose–response relationship by Kohl (2001); a review of physical fitness vs physical activity by Blair et al. (2001); and a recent quantitative meta-analysis of all studies included in the U.S. Surgeon General's report along with any subsequent papers by Williams (2001).

#### *Stroke OR cardiovascular disease*

Studies included in the recent reviews by Kohl (2001), Blair et al. (2001) and the U.S. Surgeon General's report (U.S. Department of Health and Human Services 1996) were obtained. Medline and manual searches revealed only a small number of additional articles not included in these documents, and these were obtained as well.

#### *Colon cancer OR breast cancer*

Recent reviews by Thune and Furberg (2001) and McTiernan et al. (1998) provided a comprehensive coverage of the literature. We found and obtained only a limited number of additional articles with at least one of the exposure titles (physical activity or exercise) which had not been included in either of these reviews.

*Non-insulin-dependent diabetes OR NIDDM OR type II diabetes mellitus*

A recent review by Kelley and Goodpaster (2001) provided a list of relevant papers. Our search revealed only one additional review and a small number of articles with at least one of the exposure titles (physical activity or exercise).

### 3.3 Criteria for study inclusion

The following criteria were established for inclusion of studies in the meta-analyses:

- timing of exposure (level of physical inactivity) preceded the health outcome;
- at least two categories of physical activity were included;
- the health outcome(s) of interest were defined separately (specifically, ischaemic heart disease could be separated from cardiovascular disease and ischaemic and heamorrhagic stroke were treated separately);
- the instrument used to measure physical activity was described;
- if the exposure variable was part of a larger intervention (e.g. effect of a combined diet and exercise programme), the physical inactivity component alone could be estimated;
- demographic information was provided on the study population;
- sample size was provided;
- loss during follow up was less than 20% (if applicable);
- relative risks were published or it was possible to calculate them; and
- confidence intervals or standard errors were published or could be computed.

In addition to the above criteria, if there were multiple publications concerning the same outcome from a single cohort or trial, only the most recent publication that satisfied the inclusion criteria was selected.

### 3.4 Description of included studies, including methodological qualities

*Ischaemic heart disease*

The search identified 43 papers on physical activity and ischaemic heart disease outcomes, representing 30 cohorts. After critically reviewing each of the papers against the inclusion criteria 20 papers were retained covering 18 separate cohorts. These studies are summarized in Table 10.13.

Six of the 23 excluded papers used fitness measures rather than a measure of physical activity (Blair et al. 1989; Ekelund et al. 1988; Hein et al. 1992; Lie et al. 1985; Mundal et al. 1987; Peters et al. 1983). Of the remainder, four presented total cardiovascular disease as the outcome (LaCroix et al. 1996; Sherman et al. 1994a, 1994b, 1999), nine were reports covering cohorts which were already included (Donahue et al. 1988; Johansson et al. 1988; Morris et al. 1980; Paffenbarger et al. 1984; Seccareccia and Menotti 1992; Shaper et al. 1991; Slattery and Jacobs 1988; Stampfer et al. 2000; Yano et al. 1984), in one case a relative risk could not be calculated (Pomrehn et al. 1982), and in three cases standard errors could not be determined (Garcia-Palmieri et al. 1982; Kannel et al. 1986; Lindsted et al. 1991).

Sample sizes were generally of the order of a several thousand people, with the median sample size around 8000, but ranged from 636 to 99 029. Most studies adjusted for confounding factors notably age, sex and smoking. Many studies adjusted for the intermediate factors identified as being in the causal pathway, namely blood pressure and blood cholesterol.

Mortality was ascertained by linkage or review of state, municipal or national death records. Incident cases were identified through hospital discharge lists, linkage with health registers, self-report (with and without verification by hospital records), or by abstraction and examination of hospital records.

Twelve studies were conducted in western Europe and eight studies were from North America. No studies were found from Africa, Asia or the Eastern Mediterranean. Study populations were generally of middle socioeconomic status and mostly Caucasians, an exception being men of Japanese ancestry (Rodriguez et al. 1994).

Estimates of relative risk *with* and *without* an adjustment for blood pressure and cholesterol were extracted for meta-analyses where available (see Table 10.13). The total effect of physical inactivity, not the independent effect, is required to calculate the estimates of disease burden.

*Ischaemic stroke*

Over 30 papers were considered for inclusion into our meta-analysis for ischaemic stroke. Only eight studies met our criteria, all of which had

**Table 10.13** Summary of included studies relating to ischaemic heart disease

| *Subregion* | *Study (year)* | *Name*[a] | *n* | *Cases* | *Sex* | *Age (years)* | *Outcome* | *Follow-up (years)* | *Adjustment*[b] | *RR*[c] | *Approximate SE* | *95% CI* | *PA measure*[d] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AMR-A | Folsom et al. (1997)* | ARIC | 7852 | 97 | Female | 45–64 | IHD incidence[e] | 4–7 | 1,2,3,4,5,6 | 1.39 (1.64) | 0.34 | 0.71–2.70 | Sports index |
| | | | | | | | | | | 1.56 (1.79) | 0.33 | 0.82–2.98 | Leisure index |
| | | | 6188 | 223 | Male | | | | | 1.20 (1.43) | 0.20 | 0.81–1.78 | Sports index |
| | | | | | | | | | | 1.12 (1.32) | 0.21 | 0.74–1.70 | Leisure index |
| | Lee et al. (2000) | Harvard Alumni | 7307 | 482 | Male | Mean 66.1 | IHD incidence | 5 | 1,2,4,6 | 1.51 | 0.22 | 1.05–2.48 | DTPA + walking + stairs |
| | Lee and Skerrett (2001)* | Women's Health | 39372 | 244 | Female | ≥45 | IHD incidence | 4–7 | 1,2 | 1.82 | 0.20 | 1.23–2.69 | DTPA + walking + stairs |
| | Leon et al. (1987) | MRFIT | 12138 | 225 | Male | 35–57 | IHD mortality | 6–8 | 1,2,4,5 | 1.49 (1.56) | 0.16 | 1.09–2.04 | DTPA |
| | Manson et al. (1999)* | US Nurses' Health | 72488 | 645 | Female | 40–65 | IHD mortality or AMI | 8 | 1,2,3,4,5,6 | 1.52 (1.85) | 0.15 | 1.13–2.03 | DTPA + walking + stairs |
| | Rodriguez et al. (1994) | Honolulu Heart Program | 8006 | 789 | Male | 45–68 | IHD incidence | 23 | 1,2,3,4,5,6 | 1.05 (1.22) | 0.09 | 0.88–1.26 | All PA |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sesso et al. (2000)* | Harvard Alumni | 12516 | 2135 | Male | 39–88 | IHD incidence | 16 | 1,2,3,4,6 | 1.23 (1.37) | 0.07 | 1.07–1.41 | Sports + walking + stairs |
| | Slattery et al. (1989) | US Railroad | 2548 | | Male | 22–79 | IHD mortality | 17–20 | 1,2,4,5 | 1.28 (1.39) | 0.13 | 0.99–1.63 | DTPA |
| EUR-A | Bijnen et al. (1998) | Zutphen Elderly | 802 | 90 | Male | 64–84 | IHD mortality | 10 | 1,2 | 1.18 (1.18) | 0.26 | 0.71–1.96 | DTPA |
| | Haapanen et al. (1997)* | . . . | 953 | 75 | Female | 35–63 | IHD incidence | 10 | 1,2 | 1.25 | 0.28 | 0.72–2.15 | DTPA |
| | | | 754 | 108 | Male | 35–63 | IHD incidence | 10 | | 1.98 | 0.25 | 1.18–3.15 | DTPA |
| | Kaprio et al. (2000)* | Finnish Twins | 8177 | 723 | Male | 25–68 | IHD incidence | 2–20 | 1,2,3,4,6 | 1.47 (1.92) | 0.16 | 1.07–2.01 | DTPA |
| | Lakka et al. (1994)* | Kuopio | 1166 | 42 | Male | 42–60 | AMI | 2–8 | 1,2,3,4,5,6 | 2.63 (2.94) | 0.51 | 0.97–7.15 | DTPA |
| | Menotti and Seccareccia (1985) | Italian Railroad | 99029 | 614 | Male | 40–59 | AMI mortality | 5 | None | 1.97 | 0.12 | 1.56–2.49 | OPA |
| | Morris et al. (1990) | British Civil Servants | 9376 | 474 | Male | 45–64 | IHD incidence | 10 | None | 1.32 | 0.15 | 0.98–1.77 | DTPA |
| | Pekkanen et al. (1987) | Seven Countries | 636 | 106 | Male | 45–64 | IHD mortality | 20 | 1,2,4,5 | 1.30 (1.40) | 0.19 | 0.89–1.89 | All PA |
| | Rosengren and Wilhelmsen (1997) | Goteborg | 7142 | 584 | Male | 47–55 | IHD mortality | 20 | 1,2,3,4,5,6 | 1.35 (1.45) | 0.14 | 1.03–1.78 | DTPA |

*continued*

**Table 10.13** Summary of included studies relating to ischaemic heart disease (*continued*)

| *Subregion* | *Study (year)* | *Name*[a] | *n* | *Cases* | *Sex* | *Age (years)* | *Outcome* | *Follow-up (years)* | *Adjustment*[b] | *RR*[c] | *Approximate SE* | *95% CI* | *PA measure*[d] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Salonen et al. (1982) | North Karelia | 3688 | 63 | Female | 30–59 | AMI | 6 | 1,2,3,4,5 | 1.50 (1.70)<br>2.40 (2.70) | 0.31<br>0.23 | 0.82–2.75<br>1.53–3.77 | DTPA<br>OPA |
| | | | 3978 | 89 | Male | 30–59 | IHD mortality | 6 | | 1.40 (1.60)<br>1.6 (1.70) | 0.23<br>0.19 | 0.89–2.20<br>1.10–2.32 | DTPA<br>OPA |
| | Salonen et al. (1988) | North Karelia | 15088 | 102 | Male and female | 30–59 | IHD mortality | 6 | 1,2,3,4,5,7 | 1.30 | 0.11 | 1.13–1.74 | All PA |
| | Shaper et al. (1994) | British Regional | 5694 | 311 | Male | 40–59 | IHD incidence | 9.5 | 1,2,3,5 | 2.50 | 0.22 | 1.64–3.85 | DTPA |
| | Sobolski et al. (1987) | Belgian Fitness | 2106 | 62 | Male | 40–55 | IHD incidence | 5 | none | 0.76 | 0.35 | 0.38–1.51 | All PA |

Key: SE, standard error (of log relative risk); CI, confidence interval; PA, physical activity; IHD, ischaemic heart disease; AMI, acute myocardial infarction.

[a] Name refers to the common name of the cohort study.

[b] Adjusted for: 1 = age, 2 = smoking, 3 = BMI or waist/hip ratio, 4 = blood pressure, 5 = cholesterol, 6 = type II diabetes, 7 = sex.

[c] Relative risk estimate with adjustment as indicated in footnote b. Figure in brackets indicates relative risk estimate NOT adjusted for blood pressure and cholesterol and some other factors.

[d] DTPA refers to discretionary-time activity; Sports index refers to organized sporting activities; Leisure index refers to DTPA excluding organized sports; OPA refers to occupational-related activity.

[e] Incidence includes both morbidity and mortality.

* Indicates data from study used to calculate summary relative risk for level 2 exposure (insufficiently active).

been published since 1990 (Table 10.14). The majority of studies were excluded because they did not separate the subtypes of stroke; instead they reported risk estimates for the combined outcome of ischaemic and heamorrhagic stroke. The studies included covered both males and females and the age range of 40–74 years. Seven of the eight studies were from North America (Abbott et al. 1994; Evenson et al. 1999; Gillum et al. 1996; Hu et al. 2000; Kiely et al. 1994; Lee et al. 1999; Sacco et al. 1998) and one study was conducted in Europe (Sweden) (Harmsen et al. 1990). Median sample size was811 1473.

For stroke, cases were identified through hospital discharge lists, linkage with health registers, self-report (in some cases verified by hospital records) or by abstraction and examination of hospital records. Deaths were identified through linkage with national, state or municipal registries.

Details of each study and relative risk estimates are presented in Table 10.14.

*CANCERS*

Over 100 papers published since 1980 were identified for the two site-specific cancer types, namely, colon and breast cancer. For both types of cancer, the majority of cases were identified through hospital discharge lists, cancer registries or by direct hospital recruitment (for case–control studies). In a small number of studies, self-reported data were used, but in all but one study these data were verified by review of hospital records. Deaths were identified via linkage with national, municipal or state records.

Sample sizes varied greatly, with a median sample size of 1844 for breast cancer and 1472 for colon cancer. The studies of breast cancer included only females, a single study looking at male breast cancer was excluded. Colon cancer studies appeared to cover both sexes equally. The majority of studies controlled for various important confounding or intermediary factors including age, smoking, family history of cancer and BMI. In addition, parity, use of hormone replacement therapy, use of oral contraceptives and menopausal status were controlled for in studies on breast cancer, and alcohol consumption, caloric intake and dietary factors (such as fat and fibre intake) were considered in studies on colon cancer.

The majority of studies for both types of cancer were conducted in North America, western Europe and the Western Pacific (e.g. China and Japan) (Kato et al. 1990; Matthews et al. 2001). Details of the 43 studies on breast cancer and 30 studies on colon cancer are shown in Tables 10.15 and 10.16.

*TYPE II DIABETES*

Twenty-two recent studies (see Table 10.17) were identified addressing the relationship between physical inactivity and type II diabetes. A

**Table 10.14** Summary of included studies relating to ischaemic stroke

| *Subregion* | *Study (year)* | *n* | *Cases* | *Sex* | *Age (years)* | *Outcome* | *Follow-up (years)* | *Adjustment*[a] | *RR*[b] | *Approximate SE* | *95% CI* | *PA measure*[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AMR-A | Abbott et al. (1994)* | 1854 | 110 | Male | 55–68 | Incidence[d] | 22 | 1,4,5,6,7 | 1.80 (2.00) | 0.26 | 1.10–3.10 | All PA (non-smokers) |
| | | 1257 | 116 | | | | | | 1.20 (3.7) | 0.21 | 0.80–1.80 | All PA (smokers) |
| | Evenson et al. (1999) | 14575 | 189 | Male and female | 45–64 | Incidence | 7.2 | 1,2,3,4,6,7 | 1.22 | 0.23 | 0.78–1.91 | Sport PA |
| | | | | | | | | | 1.11 | 0.15 | 0.83–1.49 | DTPA (non-sports) |
| | | | | | | | | | 1.43 | 0.21 | 0.95–2.16 | OPA |
| | Gillum et al. (1996)* | 1285 | 60 | Male | 45–64 | Incidence | 10–16 | 1,2,3,4,5,6,8 | 1.10 (1.10) | 0.36 | 0.54–2.23 | DTPA |
| | | 1083 | 186 | | 65–74 | | | | 1.34 (1.49) | 0.20 | 0.90–2.00 | DTPA |
| | | 1473 | 48 | Female | 45–64 | | | | 2.89 (3.05) | 0.61 | 0.87–9.55 | DTPA |
| | | 1240 | 179 | | 65–74 | | | | 1.47 (1.6) | 0.26 | 0.88–2.44 | DTPA |
| | | 771 | 94 | Male and female | 45–74 | | | | 1.43 (1.43) | 0.37 | 0.70–2.94 | DTPA |
| | Hu et al. (2000)* | 72488 | 258 | Female | 40–65 | Incidence | 8 | 1,2,3,4,5,6 | 1.20 (1.45) | 0.18 | 0.85–1.71 | All PA |
| | Kiely et al. (1994)* | 1228 | 107 | Male | 28–62 | Incidence | 18 | 1,2,3,4,5,6,8 | 1.89 (2.27) | 0.23 | 1.20–2.96 | All PA |
| | | 1676 | 127 | Female | | | | | 0.83 (1.05) | 0.25 | 0.51–1.35 | All PA |
| | Lee et al. (1999)* | 21823 | 437 | Male | 40–84 | Incidence | 11.1 | 1,2,3,4,5,6,7,8 | 1.05 | 0.13 | 0.82–1.36 | DTPA |
| | Sacco et al. (1998) | 284[e] | 163 | Male | ≥40 | Incidence | | 1,2,3,4,6,7,8 | 2.78 | 0.29 | 1.57–4.90 | DTPA |
| | | 394[e] | 206 | Female | | | | | 2.94 | 0.35 | 1.48–5.84 | DTPA |
| EUR-A | Harmsen et al. (1990) | 7495 | 69 | Male | 47–55 | Mortality | 11.8 | None | 1.20 | 0.27 | 0.70–2.00 | All PA |

Key: SE, standard error (of log relative risk); PA, physical activity.

[a] Adjusted for: 1 = age, 2 = smoking, 3 = BMI or waist/hip ratio, 4 = blood pressure, 5 = cholesterol, 6 = type II diabetes, 7 = sex, 8 = history of cardiovascular disease.

[b] Relative risk estimate with adjustment as indicated in footnote a. Figure in brackets indicates relative risk estimate NOT adjusted for blood pressure and cholesterol and some other factors.

[c] Sports PA refers to organized sporting activities; DTPA refers to discretionary-time activity; OPA refers to occupational-related activity.

[d] Incidence includes both morbidity and mortality.

[e] Case–control study. "*n*" is number of controls.

* Indicates data from study used to calculate summary relative risk for level 2 exposure (insufficiently active).

**Table 10.15** Summary of studies relating to breast cancer

| Subregion | Study (year) | n Cases | n Controls | Age (years) | Follow-up (years) | Adjustment[a] | RR[b] | Approximate SE | 95% CI | PA measure[c] |
|---|---|---|---|---|---|---|---|---|---|---|
| AMR-A | Albanes et al. (1989)* | 122 | 7 407[e] | 25–74 | 7–13 | 1 | 1.00 | 0.25 | 0.61–1.63 | DTPA |
| | | | | | | | 1.11 | 0.31 | 0.60–2.04 | OPA |
| | Bernstein et al. (1994) | 545 | 545 | ≤40 | | 3,4,5,7,8 | 1.25 | 0.20 | 0.84–1.85 | DTPA |
| | Breslow et al. (2001) | 138 | 6 160 | ≥50 | 8–10 | Yes | 3.03 | 0.45 | 1.25–7.32 | DTPA |
| | Calle et al. (1998) | 1 780 | 563 395[d] | ≥29 | 9 | Yes | 0.91 | 0.07 | 0.79–1.04 | OPA |
| | Carpenter et al. (1999) | 1 123 | 904 | 55–64 | | 1,3,5,8 | 1.14 | 0.10 | 0.93–1.38 | DTPA |
| | Cerhan et al. (1998)* | 46 | 1 806 | 65–102 | 11 | Yes | 5.00 | 0.74 | 1.17–21.32 | DTPA |
| | Chen et al. (1997) | 747 | 961 | 21–45 | | 1,3,4,5,8 | 1.05 | 0.13 | 0.82–1.36 | DTPA |
| | Coogan et al. (1997) | 4 863 | 6 783 | 17–74 | | 1,3,4,5,8 | 1.16 | 0.06 | 1.03–1.31 | OPA |
| | Coogan and Aschengrau (1999) | 233 | 670 | All ages | | 1 | 1.25 | 0.30 | 0.69–2.25 | OPA (ever held job with at least moderate activity) |
| | Dorgan et al. (1994) | 117 | 2 307[d] | ≥35 | 28 | 1,4,5,9 | 0.77 | 0.31 | 0.42–1.41 | All PA |
| | Fraser and Shavlik (1997) | 218 | 20 341[d] | ≥24 | 6 | 1,3,4,5,6,8,9 | 1.27 | 0.14 | 0.97–1.67 | All PA |
| | Friedenreich et al. (2001)* | 462 | 475 | <80 | | 1,2,3,6,8 | 0.87 | 0.20 | 0.59–1.29 | All PA (pre-menopausal) |
| | | 771 | 762 | <80 | | | 1.33 | 0.15 | 0.99–1.79 | All PA (post-menopausal) |
| | Frisch et al. (1987) | 69 | 5 398[d] | 18–22 | 56 | 1,2,3,4,6,7,8 | 1.86 | 0.32 | 1.00–3.47 | DTPA (college athletics) |
| | Gammon et al. (1998) | 1 668 | 1 505 | <45 | | 3,9 | 0.98 | 0.10 | 0.81–1.19 | DTPA |

*continued*

**Table 10.15** Summary of studies relating to breast cancer (*continued*)

| Subregion | Study (year) | n: Cases | n: Controls | Age (years) | Follow-up (years) | Adjustment[a] | RR[b] | Approximate SE | 95% CI | PA measure[c] |
|---|---|---|---|---|---|---|---|---|---|---|
| | Gilliland et al. (2001)* | 171 | 210 | 30–74 | | 1,4,5,6,7 | 2.70 | 0.36 | 1.33–5.47 | DTPA (post-menopausal Hispanic) |
| | | 228 | 224 | | | 1,4,5,6,7 | 2.04 | 0.29 | 1.16–3.60 | DTPA (post-menopausal non-Hispanic) |
| | | 128 | 152 | | | 1,4,5,6 | 2.04 | 0.40 | 0.93–4.47 | DTPA (pre-menopausal Hispanic) |
| | | 115 | 183 | | | 1,4,5,6 | 0.69 | 0.39 | 0.32–1.49 | DTPA (pre-menopausal non-Hispanic) |
| | Lee et al. (2001b)* | 411 | 39 322 | ≥45 | 4 | 1,3,4,5,6,7,8,9 | 1.16 | 0.15 | 0.87–1.56 | EE of DTPA + stairs (all women) |
| | | 261 | 21 482 | | | 1,3,4,5,6,7,8 | 1.28 | 0.19 | 0.88–1.86 | EE of DTPA + stairs (post-menopausal) |
| | Marcus et al. (1999) | 790 | 864 | 20–74 | | Not specified | 1.25 | 0.13 | 0.97–1.61 | DTPA (at age 12) |
| | McTiernan et al. (1996)* | 537 | 492 | 50–64 | | 1 | 1.67 | 0.21 | 1.10–2.52 | DTPA |
| | Mittendorf et al. (1995) | 6 888 | 9 539 | 17–74 | | Yes | 1.00 | 0.10 | 0.80–1.20 | DTPA (at age 14–22) |
| | Moore et al. (2000)* | 1 380 | 37 105[d] | 55–69 | 12 | 1,3,5,6,8,9 | 1.09 | 0.09 | 0.91–1.30 | DTPA |
| | Rockhill et al. (1998) | 372 | 116 671[d] | 25–42 | 16 | Yes | 0.91 | 0.18 | 0.64–1.29 | DTPA in adolescence |
| | Rockhill et al. (1999)* | 3 137 | 121 701[d] | 30–55 | 16 | 1,3,4,5,6,8,9 | 1.12 | 0.05 | 1.02–1.24 | DTPA |
| | Sesso et al. (1998) | 109 | 1 566[d] | ≥40 | 31 | 1,3 | 0.56 | 0.43 | 0.24–1.29 | DTPA (pre-menopausal) |
| | | | | | | | 2.04 | 0.29 | 1.16–3.60 | DTPA (post-menopausal) |
| | Shoff et al. (2000) | 4 614 | 5 817 | 20–74 | | 3,4,5,8,9 | 1.08 | 0.08 | 0.92–1.26 | DTPA |
| | Steenland et al. (1995) | 163 | 14 407[e] | 25–74 | 13–17 | Yes | 1.11 | 0.30 | 0.62–2.00 | All PA |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sternfeld (1992) | 254 | 201 | All ages | | Not specified | 0.45 | 0.34 | 0.23–0.88 | DTPA |
| | Taioli et al. (1995) | 195 | 191 | ≥25 | | 1,3,4 | 1.11 | 0.51 | 0.41–3.02 | DTPA (pre-menopausal) |
| | | 421 | 337 | | | | 0.77 | 0.47 | 0.31–1.93 | DTPA (post-menopausal) |
| | Wyrwich and Wolinsky (2000) | 77 | 3 131 | 70–98 | 7 | 1,3 | 2.38 | 0.41 | 1.07–5.32 | All PA |
| | Wyshak and Frisch (2000) | 175 | 3 940[e] | 21–80 | 15 | 1,2,3,4,6,7,8 | 1.65 | 0.16 | 1.21–2.26 | DTPA (college athletics) |
| | | 12 | | 21–44 | 15 | 1,2,3,4,7,8 | 6.10 | 0.69 | 1.58–23.59 | DTPA (college athletics) |
| EUR-A | Fioretti et al. (1999) | 1 041 | 1 002 | 15–79 | | 1,3,6,7 | 1.18 | 0.31 | 0.64–2.16 | All PA (pre-menopausal) |
| | | | | | | | 1.35 | 0.26 | 0.81–2.45 | All PA (post-menopausal) |
| | Levi et al. (1999)* | 245 | 371 | 27–74 | | 1,4,5,8,9 | 2.00 | 0.25 | 1.23–3.26 | DTPA (at 30–39 years) |
| | | | | | | | 1.96 | 0.34 | 1.01–3.82 | OPA (at 30–39 years) |
| | Mezzetti et al. (1998)* | 989 | 841 | 18–74 | | 1,3 | 1.39 | 0.22 | 0.91–2.13 | OPA (pre-menopausal) |
| | | 1 577 | 1 745 | | | | 1.61 | 0.17 | 1.16–2.23 | OPA (post-menopausal) |
| | Moradi et al. (2000) | 3 347 | 3 455 | 50–74 | | Yes | 1.25 | 0.06 | 1.11–1.41 | DTPA recently |
| | Moradi et al. (1999) | 22 840 | 982 270[d] | All ages | 19 | 1 | 1.18 | 0.05 | 1.07–1.30 | OPA |
| | Pukkala et al. (1993) | 228 | 10 038[d] | 18–22 | 24 | | 1.43 | 0.07 | 1.25–1.64 | DTPA |
| | Thune et al. (1997) | 98 | 25 624[d] | 20–69 | 14 | 1,3,4 | 1.30 | 0.26 | 0.78–2.16 | DTPA (pre-menopausal) |
| | | 98 | | | | | 1.00 | 0.17 | 0.72–1.40 | DTPA (post-menopausal) |
| | | 248 | | | | | 1.22 | 0.25 | 0.75–1.99 | OPA (pre-menopausal) |
| | | 248 | | | | | 1.15 | 0.18 | 0.81–1.64 | OPA (post-menopausal) |
| | Verloop et al. (2000) | 918 | 918 | 20–54 | | 1,2,3,4,8 | 1.45 | 0.16 | 1.06–1.98 | DTPA |
| EUR-B | Dosemeci et al. (1993) | 241 | 244 | ≥18 | | 1,2 | 0.71 | 0.63 | 0.21–2.46 | OPA |

*continued*

**Table 10.15** Summary of studies relating to breast cancer (*continued*)

| | | n | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Subregion* | *Study (year)* | *Cases* | *Controls* | *Age (years)* | *Follow-up (years)* | *Adjustment*[a] | *RR*[b] | *Approximate SE* | *95% CI* | *PA measure*[c] |
| WPR-A | Friedenreich and Rohan (1995) | 110 | 110 | 20–74 | | Yes | 1.67 | 0.35 | 0.84–3.31 | DTPA (pre-menopausal) |
| | | 258 | 258 | | | | 1.37 | 0.26 | 0.82–2.28 | DTPA (post-menopausal) |
| | Hirose et al. (1995) | 606 | 14 864 | All ages | | Not specified | 1.35 | 0.13 | 1.05–1.74 | DTPA (pre-menopausal) |
| | | 439 | 6 170 | | | | 1.39 | 0.15 | 1.04–1.87 | DTPA (post-menopausal) |
| | Hu et al. (1997) | 87 | 202 | All ages | | Yes | 0.99 | 0.32 | 0.53–1.85 | DTPA (pre-menopausal) |
| | | 67 | 159 | | | | 1.89 | 0.53 | 0.67–5.33 | DTPA (post-menopausal) |
| | Ueji et al. (1998) | 148 | 296 | 26–69 | | 3,4,5,8 | 3.33 | 0.59 | 1.05–10.59 | DTPA (pre-menopausal) |
| | | | | | | | 2.00 | 0.71 | 0.50–8.04 | DTPA (post-menopausal) |
| | | | | | | | 1.67 | 0.62 | 0.49–5.62 | OPA (pre-menopausal) |
| | | | | | | | 1.43 | 0.57 | 0.47–4.37 | OPA (post-menopausal) |
| WPR-B | Matthews et al. (2001) | 1 459 | 1 556 | 25–64 | | 1,5,8,9 | 2.13 | 0.14 | 1.62–2.80 | DTPA (all ages) |

Key: SE, standard error (of log relative risk); PA, physical activity; EE, energy expenditure.

[a] Adjusted for: 1 = age, 2 = smoking, 3 = BMI or waist/hip ratio, 4 = parity, 5 = age at first birth, 6 = use of hormone replacement therapy, 7 = use of oral contraceptives, 8 = family history of breast cancer, 9 = menopausal status.

[b] Relative risk estimate with adjustment as indicated in footnote a.

[c] DTPA refers to discretionary-time activity; OPA refers to occupational-related activity.

[d] Cohort/cross-sectional study – number of controls is total sample size.

* Indicates data from study used to calculate summary relative risk for level 2 exposure (insufficiently active).

**Table 10.16** Summary of studies relating to colon cancer

| Subregion | Study (year) | n: Cases | n: Controls | Sex | Age (years) | Follow-up (years) (cohort) | Adjustment[a] | RR[b] | Approximate SE | 95% CI | PA measure[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AMR-A | Ballard-Barbash et al. (1990)* | 79 | 2308[d] | Female | 30–62 | 28 | 1,2,3,4 | 1.11 | 0.28 | 0.64–1.82 | All PA |
| | | 73 | 1906[d] | Male | | | | 1.78 | 0.29 | 1.02–3.18 | All PA |
| | Brownson et al. (1989)* | 1993 | 9965 | Male | ≥20 | | 1 | 1.43 | 0.16 | 1.00–1.90 | OPA |
| | Brownson et al. (1991)* | 1838 | 14497 | Male | ≥20 | | 1,2 | 1.20 | 0.10 | 1.00–1.50 | OPA |
| | Garabrant et al. (1984) | 2950 | | Male | 20–64 | | 1 | 1.67 | 0.07 | 1.46–1.92 | OPA |
| | Giovannucci et al. (1995)* | 203 | 47723[d] | Male | 40–75 | 6 | 1,2,3,4,6,8 | 1.06 | 0.20 | 0.72–1.57 | DTPA |
| | Lee et al. (1991) | 225 | 17148[d] | Male | 30–79 | 23 | 1 | 1.92 | 0.31 | 1.05–3.53 | DTPA |
| | Lee et al. (1997) | 217 | 21807[d] | Male | 40–84 | 10.9 | 1,3,4 | 0.83 | 0.18 | 0.59–1.19 | DTPA |
| | Longnecker et al. (1995)* | 163 | 703 | Male | ≥31 | | 1,2,3,4,5,6,8 | 1.27 | 0.40 | 0.58–2.78 | OPA |
| | | | | | | | | 2.78 | 0.60 | 0.86–9.01 | DTPA |
| | Marcus et al. (1994) | 536 | 2315 | Female | <75 | | 1,3,8 | 1.02 | 0.11 | 0.82–1.27 | All PA (at age 14–22) |
| | Markowitz et al. (1992)* | 308 | 1164 | Male | All ages | | 1 | 2.00 | 0.25 | 1.23–3.26 | OPA |
| | Martinez et al. (1997)* | 161 | 67802[d] | Female | 30–55 | 16 | 1,2,3,4,6,8 | 1.28 | 0.22 | 0.83–1.97 | DTPA |
| | Severson et al. (1989)* | 192 | 8006[d] | Male | 46–68 | 18–21 | 1,3 | 1.41 | 0.17 | 1.01–1.97 | All PA |
| | Slattery et al. (1999)* | 1993 | 2410 | Male and female | | | 1,2,3,6 | 1.35 | 0.13 | 1.05–1.74 | DTPA (males) |
| | | | | | | | | 1.41 | 0.14 | 1.07–1.86 | DTPA (females) |
| | Slattery et al. (1988)* | 110 | 180 | Male | 40–79 | | 1,3,5,6 | 1.10 | 0.32 | 0.61–2.13 | All PA |
| | | 119 | 204 | Female | | | | 1.14 | 0.29 | 0.62–1.94 | All PA |

*continued*

**Table 10.16** Summary of studies relating to colon cancer (*continued*)

| Subregion | Study (year) | n Cases | n Controls | Sex | Age (years) | Follow-up (years) (cohort) | Adjustment[a] | RR[b] | Approximate SE | 95% CI | PA measure[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thun et al. (1992) | 611 | 2073 | Male | | | 1,3,6,8 | 1.67 | 0.37 | 0.81–3.44 | All PA |
| | | 539 | 2081 | Female | | | | 1.11 | 0.41 | 0.50–2.48 | All PA |
| | Vena et al. (1985) | 210 | 1431 | Male | 30–79 | | 1 | 1.97 | 0.18 | 1.38–2.80 | OPA (time in sedentary job) |
| | White et al. (1996)* | 251 | 233 | Male | 30–62 | | 1 | 1.27 | 0.20 | 0.86–1.87 | All PA |
| | | 193 | 194 | Female | | | | 1.49 | 0.32 | 0.80–2.79 | All PA |
| | Whittemore et al. (1990) | 61 | 255 | Male | 20–79 | | | 1.59 | 0.20 | 1.07–2.35 | DTPA |
| | | | | | | | | 2.50 | 0.43 | 1.08–5.81 | OPA |
| | | 46 | 198 | Female | | | | 2.00 | 0.26 | 1.20–3.33 | DTPA |
| | | | | | | | | 1.20 | 0.51 | 0.44–3.27 | OPA |
| EUR-A | Clemmensen (1998) | 88 | 5248[d] | Male | 40–59 | 15 | Not specified | 2.00 | 0.25 | 1.23–3.26 | All PA |
| | Gerhardsson et al. (1986) | 5100 | 1055715[d] | Male | 20–64 | 19 | 1 | 1.3 | 0.07 | 1.13–1.49 | OPA |
| | Gerhardsson et al. (1988) | 121 | 16477[d] | Male and female | 42–82 | 14 | 1,7 | 3.6 | 0.52 | 1.3–9.8 | All PA |
| | Gerhardsson et al. (1990) | 163 | 624 | Male | 40–79 | | 1,3,5,6 | 2.33 | 0.50 | 0.64–4.52 | All PA |
| | | 189 | 624 | Female | | | | 1.69 | 0.48 | 0.91–5.96 | All PA |
| | Lynge and Thygesen (1988) | | 2000000[d] | Male | 20–64 | 11 | 1 | 1.38 | 0.16 | 1.01–1.89 | OPA |
| | | | | Female | | | | 1.73 | 0.24 | 1.06–2.68 | OPA |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tavani et al. (1999)* | 688 | 2073 | Male | 19–74 | | 1,4,5 | 1.41 | 0.16 | 1.03–1.93 | OPA at age 30–39 |
| | | 537 | 2081 | Female | 19–74 | | | 2.04 | 0.20 | 1.38–3.02 | OPA at age 30–39 |
| | Thune and Lund (1996) | 236 | 53242[d] | Male | 40–54 | 16.3 | 1,3 | 1.03 | 0.22 | 0.67–1.59 | All PA |
| | | 99 | 28274[d] | Female | | | | 1.59 | 0.25 | 0.97–2.59 | All PA |
| EUR-B | Dosemici et al. (1993) | 93 | 486 | Male | All ages | | 1,2 | 1.67 | 0.09 | 1.40–1.99 | OPA |
| WPR-A | Fraser and Pearce (1993) | 1651 | Population | Male | All ages | | Not specified | 1.25 | 0.08 | 1.07–1.46 | OPA |
| | Kato et al. (1990) | 1716 | 16600 | Male | ≥20 | | 1,2,4,8 | 1.92 (proximal) | 0.17 | 1.38–2.67 | OPA |
| | | | | | | | | 1.52 (distal) | 0.12 | 1.19–1.94 | OPA |
| | Kato et al. (1990) | 132 | 528 | Male and female | | | Not specified | 1.67 | 0.28 | 0.96–2.89 | DTPA |
| | | | | | | | | 2.00 | 0.28 | 1.16–3.46 | OPA |
| WPR-B | Tang et al. (1999) | 71 | 71 | Female | 33–80 | | 1,2,4,6 | 5.26 | 0.64 | 0.45–5.56 | DTPA |
| | | 92 | 92 | Male | | | | 1.59 | 0.70 | 1.33–20.74 | DTPA |
| | Whittemore et al. (1990) | 81 | 567 | Male | 20–79 | | Not specified | 0.85 | 0.40 | 0.39–1.87 | DTPA |
| | | | | | | | | 1.41 | 0.46 | 0.57–3.47 | OPA |
| | | 66 | 305 | Female | | | | 2.50 | 0.47 | 1.00–6.28 | DTPA |
| | | | | | | | | 1.69 | 0.57 | 0.55–5.18 | OPA |

Key: SE, standard error (of log relative risk); PA, physical activity.

[a] Adjusted for: 1 = age, 2 = smoking, 3 = BMI or waist/hip ratio, 4 = alcohol consumption, 5 = caloric intake, 6 = other dietary factors (e.g. fat, fibre), 7 = sex, 8 = family history of colon cancer.

[b] Relative risk estimate with adjustment as indicated in footnote a.

[c] OPA refers to occupational-related activity; DTPA refers to discretionary-time activity.

[d] Cohort/cross-sectional study – number of controls is total sample size.

* Indicates data from study used to calculate summary relative risk for level 2 exposure (insufficiently active).

**Table 10.17** Summary of studies relating to type II diabetes

| Subregion | Author (year) | n Cases | n Controls | Sex | Age (years) | Follow-up (years) (cohort) | Adjustment[a] | RR[b] | Approximate SE | 95% CI | PA measure[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AFR-D | Dowse et al. (1991)* | 288 | 2 362[d] | Male | 25–74 | | 1,3,6 | 4.31 | 0.24 | 1.07–2.69 | All PA |
| | | 314 | 2 669[d] | Female | | | | 1.70 | 0.75 | 1.00–18.61 | All PA |
| AFR-E | Levitt et al. (1999) | 69 | 974[d] | Male and female | ≥15 | | 1,3,6,7 | 1.75 | 0.25 | 1.07–2.86 | DTPA |
| AMR-A | Folsom et al. (2000)* | 1 997 | 34 257[d] | Female | 55–69 | 12 | 1,2,3,6 | 1.27 | 0.06 | 1.13–1.43 | DTPA |
| | Fulton-Kehoe et al. (2001)* | 167 | 1 100 | Male and female | 20–74 | | 1,3,6,7 | 1.39 | 0.30 | 0.77–2.50 | All PA |
| | Gurwitz et al. (1994) | 185 | 2 737[d] | Male and female | ≥65 | 6 | 1,4,7 | 1.5 | 0.19 | 1.03–2.18 | DTPA |
| | Helmrich et al. (1994) | 202 | 5 990[d] | Male | | 14 | 1,3,4,6 | 1.32 | 0.1 | 1.09–1.61 | DTPA |
| | Hu et al. (1999)* | 1 419 | 70 102[d] | Female | 40–65 | 12 | 1,2,3,4,5,6 | 1.30 | 0.09 | 1.09–1.55 | DTPA |
| | Hu et al. (2001)* | 1 058 | 37 918[d] | Male | 40–75 | 10 | 1,2,3,6 | 1.45 | 0.12 | 1.15–1.83 | DTPA |
| | James et al. (1998)* | 78 | 916[d] | Male and female | 30–55 | 5 | 1,3,7 | 2.86 | 0.54 | 1.00–8.16 | DTPA |
| | Kriska et al. (1993) | 131 | 353[d] | Male and female | 37–59 | | 1,3,7 | 2.17 | 0.26 | 1.30–3.61 | DTPA before age 35 |
| | Leonetti et al. (1989) | 78 | 79 | Male | Mean 61 | | 1,3,6 | 1.69 | 0.22 | 1.10–2.60 | DTPA age 15–20 |
| | Manson et al. (1991) | 1 303 | 87 253[d] | Female | 34–59 | 8 | 1,3,6 | 1.20 | 0.06 | 1.07–1.35 | DTPA |
| | Manson et al. (1992) | 285 | 21 271[d] | Male | 40–84 | 5 | 1,2,3,4,5 | 1.43 | 0.14 | 1.09–1.88 | DTPA |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EUR-A | Baan et al. (1999)* | 69 | 503[d] | Male | 55–75 | | 1,2,3,6 | 1.39 | 0.38 | 0.66–2.93 | DTPA |
| | | 49 | 513[d] | Female | | | | 2.56 | 0.48 | 1.00–6.56 | DTPA |
| | Haapanen et al. (1997)* | 64 | 891[d] | Male | 35–63 | 10 | 1,2 | 1.54 | 0.31 | 0.83–2.84 | DTPA |
| | | 54 | 973[d] | Female | | | | 2.64 | 0.37 | 1.28–5.45 | DTPA |
| | Lynch et al. (1996) | | 897[d] | Male | Middle aged | | 1,3,6 | 2.27 | 0.35 | 1.14–4.51 | DTPA |
| | Perry et al. (1995) | 194 | 7735[d] | Male | 40–59 | 11–13 | 1,2,3,4,5 | 2.50 | 0.35 | 1.26–4.96 | DTPA |
| | Tuomilehto et al. (2001) | 27 | 265[d] | Male and female | 40–65 | Mean 3.3 | 3 | 3.33 | 0.5 | 1.25–8.87 | DTPA |
| | Wannamethee et al. (2000)* | 196 | 5159[d] | Male | 40–59 | 16.8 | 1,2,3,4,5 | 1.61 | 0.29 | 0.91–2.85 | DTPA |
| WPR-A | Okada et al. (2000) | 444 | 6013[d] | Male | 35–60 | 6–16 | 1,2,3,4,6 | 1.33 | 0.11 | 1.07–1.65 | DTPA |
| | Todoroki et al. (1994)* | 48 | 1113[d] | Male | 49–56 | | 2,3,6 | 2.00 | 0.46 | 0.81–4.93 | DTPA |
| WPR-B | Pan et al. (1997) | 2731 | 11028[d] | Male and female | 25–64 | | 1,3,4,6,7 | 1.18 | 0.05 | 1.07–1.30 | OPA |
| | Taylor et al. (1984) | | 640[d] | Male | ≥20 | | 1,3 | 2.50 | 0.44 | 1.06–5.92 | All PA (Melanesians) |
| | | | 595[d] | | | | | 2.10 | 0.25 | 1.29–3.43 | All PA (Indians) |

Key: SE, standard error (of log relative risk); PA, physical activity.

* Indicates data from study used to calculate summary relative risk for level 2 exposure (insufficiently active).

[a] Adjusted for: 1 = age, 2 = smoking, 3 = BMI or waist/hip ratio, 4 = blood pressure, 5 = cholesterol, 6 = family history of type II diabetes, 7 = sex.

[b] Relative risk estimate with adjustment as indicated in footnote a.

[c] DTPA refers to discretionary-time activity; OPA refers to occupational-related activity.

[d] Cohort/cross-sectional study – number of controls is total sample size.

diverse range of populations have been studied from the regions of Africa (Mauritius, South Africa and the United Republic of Tanzania), Asia (China), the Western Pacific (Japan and Fiji) as well as North America and western Europe.

For type II diabetes, cases in all case–control studies were identified using oral glucose tolerance tests (OGTT). In the majority of cohort studies, identification was by OGTT or fasting plasma glucose tests at follow-up, or by self-report, validated by physician or medical record review. In only one case was unverified self-reported data used.

Sample sizes ranged widely with a median sample size of 1113. All studies adjusted for a variety of important confounding or intermediary factors including age, BMI, blood pressure, cholesterol and family history of diabetes.

### 3.5 Methods for meta-analysis

Our general method for meta-analyses was similar to that used by Berlin and Colditz (1990) and Eaton (1992) and combined estimates of the log relative risks using an inverse-variance weighting scheme (Berlin and Colditz 1990; Eaton 1992). This method gives relatively more importance to studies with a larger number of cases and produces a wider confidence interval for the pooled relative risk estimate than would be obtained by other methods (such as the Mantel-Haenszel method). Confidence intervals for the summary risks were derived using a pooled standard error.

For ischaemic heart disease and ischaemic stroke we conducted two different meta-analyses. Firstly, we pooled risk estimates derived from analyses which *had* adjusted for two intermediary variables (blood pressure and cholesterol) and secondly, we pooled estimates of risk *without* adjustment for these intermediary variables. The former (with adjustment) removes the effect due to other factors and identifies the independent risk due to physical inactivity. Estimates of risk *without* adjustment for other variables in the causal pathway indicate the total effect of exposure to inactivity. The first method partials out the contribution of inactivity to various disease end-points while the second is useful in calculating the total effect of removing exposure to inactivity (Greenland 1987). We report both results to enable comparison with results from previous meta-analyses, all of which used adjusted data, and to allow computation of avoidable burden of disease (which required the unadjusted analyses). For type II diabetes and breast and colon cancer, estimates of risk were computed using only adjusted data as noted in Tables 10.15–10.17.

The problems associated with measurement of behavioural risk factors are well known and to date few satisfactory solutions are available. Given the difficulties associated with assessing a complex exposure variable like physical inactivity and the heterogeneity among the instruments used across the epidemiological studies, one approach is to introduce an adjustment at the analytical stage. Adjustment for measurement error within the meta-analysis has been previously applied to other risk factors (Bashir and Duffy 1997). We employed this technique in our analyses and present the results both adjusted for measurement error and unadjusted for measurement error.

Overall three separate analytical approaches were conducted to derive summary estimates of relative risk, as summarized below.

- *Adjusted for intermediary variables*: This method was undertaken for all disease outcomes and used pooled relative risk estimates from studies in which the analyses *had* controlled for the intermediate factors (blood cholesterol and blood pressure). These results have not incorporated the adjustment for measurement error and so can be compared to other published results that have controlled for intermediaries.
- *Adjusted for intermediary variables AND adjusted for measurement error*: This method is the same as above with the addition of a statistical adjustment for measurement error. This method was conducted for all disease outcomes and represents an extension of the above method.
- *Unadjusted for intermediary variables AND adjusted for measurement error*: This method pooled relative risk estimates from studies in which the analyses *had not* controlled for blood pressure and cholesterol. It was conducted for only ischaemic heart disease and ischaemic stroke and, for those studies without unadjusted risk estimates, the adjusted risk estimates were included.

### *Measurement error*

The major sources of error arise from the variability in the measurement and/or definitions of the health outcome and the exposure variable (i.e. physical inactivity). A further source of variability may be due to the timing of the exposure. These will be discussed in turn below.

#### *Error due to variable measures of exposure*

In general, measurement error is a product of the different ways in which physical inactivity is measured and/or categorized. Using different measures and definitions can result in quite different estimates of the level of exposure to physical inactivity. We identified three main sources of potential measurement error for exposure.

Firstly, the questionnaires used in the epidemiological studies included in our meta-analyses vary in their attempt to measure physical activity undertaken in different domains. The studies included for ischaemic heart disease mostly evaluated discretionary-time physical activity (Haapanen et al. 1997; Lakka et al. 1994; Leon et al. 1987; Rosengren and Wilhelmsen 1997; Shaper et al. 1994; Slattery et al. 1989), although in some studies this was defined as “sport” and “leisure activities” (Folsom et al. 1997) and in other studies it was extended to include other activities such as walking and stair climbing (Lee and Skerrett 2001; Lee et al. 2000; Manson et al. 1999). In the Harvard Alumni study “sports” activity plus walking and stair climbing were assessed (Sesso et al. 2000). In several studies “all” physical activity was evaluated but the exact meaning and coverage of domains required a careful inspection of the specific instruments (Morris et al. 1990; Pekkanen et al. 1987; Rodriguez et al. 1994; Salonen et al. 1988; Sobolski et al. 1987). Only one study included in our meta-analysis provided an estimate of risk based on only occupational physical activity and one other study provided separate relative risk estimates for occupational and discretionary-time activity (Menotti and Seccareccia 1985; Salonen et al. 1982). It is notable that the majority of studies published post 1980 focus more on discretionary-time activity whereas literature published between 1958–1980 is dominated by studies of work-related activity.

Pooling results from studies with measures of exposure across discretionary time, sports, walking, stair climbing and “all” activity could have a marked affect on the overall estimates of risk. One solution, previously used by Berlin and Colditz (1990), is to separately pool results from studies assessing different domains (e.g. occupation only, discretionary time only). However, in this study the pooled summary relative risk estimates were applied to prevalence estimates of exposure in which multiple domains had been considered. We therefore considered the inclusion of studies with diverse definitions of activity, possibly across more than one domain as acceptable. Nonetheless, this source of heterogeneity among the literature is noted, as is the desirability for much greater comparability of measures of exposure between studies.

A second source of measurement error could arise from the different instruments used to assess exposure in the various domains. Five of the 19 included cohort studies used the Minnesota Leisure Time Physical Activity questionnaire and three used the Harvard Alumni instrument, but the remaining 11 studies used different and sometimes unspecified survey tools. Different questionnaires have different properties and concomitant variation in the level of validity and reliability. The instruments used in the studies included in our meta-analyses assessed physical activity over differing referent time periods (e.g. the previous year, last week or usual week) and used various response formats (Folsom et al. 1997; Lakka et al. 1994; Lee and Paffenbarger 2000). To address this concern we included an adjustment for measurement error in our meta-analyses using information on the reliability of each instrument. The rationale and methodology are described below.

A third potential source of error relating to the exposure variable may result from the different ways in which physical activity data are categorized. For instance, different studies have used different methods of categorization (e.g. tertiles, quartiles, quintiles, sextiles) (Folsom et al.

1997; Lee and Paffenbarger 2000; Leon et al. 1987; Rodriguez et al. 1994; Rosengren and Wilhelmsen 1997; Sesso et al. 2000; Shaper et al. 1994), but not all studies provide a full description of the level of activity in each category to facilitate between-study comparison. In addition to the variability between studies there is also likely to be within-category variability (Blair and Jackson 2001). Indeed, Berlin and Colditz (1990) discussed this problem and concluded that this could explain why some studies failed to show a protective affect due to physical activity.

We attempted to reduce the error from pooling results from different studies using different categories by identifying from each study the categories of activity most consistent with our definitions of exposure. We selected the "sedentary" or lowest category from each study as the "most exposed" group and this was deemed most comparable to our level 1 exposure (inactive). Similarly, the categories of activity within each study were reviewed to identify the most comparable group(s) for our level 2 exposure (insufficient activity). Finally, and most importantly, we extracted from each study the estimate of relative risk pertaining to a referent group equivalent to our level 3 exposure, namely, a level of activity equal to at least 150 minutes of moderate-intensity activity per week (at least 2.5 hours of activity per week or an energy expenditure of at least 4000 kJ/week). Some studies did not clearly define this group and in these cases we carefully reviewed each category within the study and made a subjective assessment. In this regard, our meta-analysis differs from previous reviews which have chosen to assess the relative risk of inactivity using a referent group defined as the "most active" or "vigorous activity" or "high fitness".

*Error due to measures of disease end-points*

Another possible source of measurement error arises from different definitions or classifications of the disease end-points, particularly when disease subtypes exist within a health outcome. For example, studies with ischaemic heart disease as an outcome may include mortality and/or morbidity from all types of ischaemic heart disease (including angina pectoris), only myocardial infarction or myocardial infarction and sudden death combined. However, the etiology of these conditions may differ, as may the contribution of physical inactivity.

In assessing ischaemic heart disease, Berlin and Colditz (1990) undertook separate meta-analyses for acute myocardial infarction, ischaemic heart disease incidence and for ischaemic heart disease mortality. They found no difference in the relative risk estimates from the analysis of each outcome separately, although the strength of association (defined by the range of confidence intervals) was greater for mortality than morbidity. Eaton (1992) examined the differences between pooled estimates from studies using ischaemic heart disease mortality and those using clinical ischaemic heart disease as health outcomes and also found no difference in the size or the strength of the association. Therefore, given no evidence to the contrary, we combined ischaemic heart disease mortality and morbidity in our meta-analyses.

There appears to be no association between physical activity and hemorrhagic stroke. As a result in studies assessing stroke, misclassification of subtypes may have led to null associations between physical activity level and disease outcome (Kohl 2001). Therefore, for inclusion in our meta-analyses, only studies that clearly differentiated and reported results for ischaemic stoke were included.

For type II diabetes, colon cancer and breast cancer there is a paucity of information on the level of any misclassification and the effect on relative risk estimates. However, any misclassification of colon cancer (i.e. colon, colorectal and rectal cancers) would, if random, most likely underestimate the relationship between physical activity and risk for colon cancer. The positive effect of physical activity would be diluted because of null associations included due to misclassification.

*Error due to timing and duration of exposure*

Epidemiological data may also be inconsistent due to the timing of the exposure, in this case physical inactivity. However it is simpler to consider the timing of physical activity and ask when during the life course is activity required for risk reduction? For ischaemic heart disease and type II diabetes the activity is required to be regular and recent for risk reduction. However, for other conditions (e.g. breast cancer, colon cancer) activity during childhood or adolescence may be important to reduce risk.

Among the studies included in the meta-analyses a range of follow-up periods can be seen—for example, from 2 to 23 years for ischaemic heart disease, from 8 to 22 years for ischaemic stroke and from 4 to 56 years for breast cancer. Measurement error associated with assessing long-term physical activity patterns by a questionnaire administered only at baseline is likely to be important. It was, however, not possible to account for this in our meta-analyses but it is highly recommended that this issue be explored in future research.

*Adjustment for measurement error*

We considered the issue of measurement error associated with self reported recall of physical (in)activity and concluded that such error could lead to an underestimate of the association between physical activity and disease end-points. Thus, an adjustment for measurement error was made to each estimate of relative risk extracted from the individual studies based on the reliability of the instrument used to measure exposure. Specifically, the adjustment involved multiplying the beta coefficients (log relative risks) by the inverse of the study-specific test–retest correlation coefficient as previously used with other risk factors (Bashir and Duffy 1997), although we found no prior evidence of its use with physical inactivity.

The test–retest coefficient for each instrument was obtained in the first instance from the article as cited by the authors of the epidemiological study. When this was not available we searched the published literature including a compendium of instruments which contained an excellent summary of test–retest reliability data for many instruments (Pereira et al. 1997). If no information was found for a specific instrument but a sufficiently detailed description was available, we assigned a test–retest coefficient based on the correspondence between characteristics of the instrument as described by the authors and other known instruments. In those cases where little or no information on the instrument was provided the average score of known instruments was applied. This process was undertaken for all studies included for each of the disease outcomes. Table 10.18 reports the test–retest coefficient for the instruments used in studies addressing ischaemic heart disease.

*Heterogeneity*

Although the fixed-effects model gives relatively more importance to bigger studies than smaller studies in the summary relative risk estimate, the effect of any heterogeneity not accounted for by study size remains. Despite our study inclusion criteria heterogeneity among the studies was significant for all conditions, except for ischaemic heart disease, as we describe below. No attempt to identify the sources of heterogeneity was undertaken. However, it is probable that differences in study design such as combining studies with different types of physical activity, different measurement instruments, different follow-up time, and differences in disease outcomes contributed to the heterogeneity (Berlin and Colditz 1990). Tests of heterogeneity and bias were conducted to assess the quality of the data as well as to reveal any evidence of heterogeneity and/or publication bias. The extent of bias was assessed by regressing the standard errors to the relative risk estimates and testing whether the regression coefficient was equal to zero (Sterne and Egger 2001).

Heterogeneity was assessed using funnel plots by drawing 95% confidence limits around the summary risk estimate for various values of the standard error. In the absence of heterogeneity, 95% of the point estimates should lie within these limits.

## 3.6 Attenuation for age

The relative risk associated with physical activity and some disease endpoints has been shown to be lower for older age groups compared with younger age groups (Sesso et al. 2000). This is consistent with an age attenuation seen in other intermediate risk factors such as systolic blood pressure and cholesterol (MacMahon et al. 1990). It is desirable for any calculation of attributable burden to include an attempt to better represent the differential risk across age. However, overall there were too few

**Table 10.18** Test–re-test reliability for instruments used in studies on ischaemic heart disease

| *Authors* | *Year* | *Study name* | *Instrument* | *Test–re-test reliability* |
|---|---|---|---|---|
| Sesso et al. | 2000 | Harvard Alumni | Harvard Alumni | 0.72 |
| Morris et al. | 1990 | British Civil Servants | (No specific name) | 0.75 |
| Rodriguez et al. | 1994 | Honolulu | Framingham | 0.45 |
| Menotti and Seccareccia | 1985 | Seven Counties Italian Railroad | (No specific name) | 0.70 |
| Rosengren and Wilhelmsen | 1997 | Goteborg Primary Prevention | (No specific name) | 0.75 |
| Lee and Paffenbarger | 2000 | Harvard Alumni | Harvard Alumni | 0.72 |
| Lee et al. | 2001a | US Women's Health | Harvard Alumni | 0.72 |
| Leon et al. | 1987 | MRFIT | Minnesota LTPA | 0.92 |
| Lakka et al. | 1994 | Kuopio | Minnesota LTPA | 0.92 |
| Sobolski et al. | 1987 | Belgian Fitness | Minnesota LTPA | 0.92 |
| Shaper et al. | 1994 | British Regional | Minnesota LTPA | 0.92 |
| Folsom et al. | 1997 | ARIC | Baecke Physical Activity | 0.93 |
| Salonen et al. | 1988 1982 | North Karelia (two cohorts) | (No specific name) | 0.75 |
| Slattery et al. | 1989 | US Railroad | Minnesota LTPA (Early version) | 0.82 |
| Pekkanen et al. | 1987 | Finish Cohort | (No specific name) | 0.75 |
| Haapanen et al. | 1997 | Finish Cohort | (No specific name) | 0.80 |
| Manson et al. | 1999 | US Nurses' Health | (No specific name) | 0.79 |
| Kaprio et al. | 2000 | Finnish Twins | (No specific name) | 0.75 |
| Bijnen et al. | 1998 | Zutphen Elderly | Zutphen Elderly | 0.93 |

data on physical inactivity by age to compute age-specific estimates of relative risks.

In lieu of this, the summary relative risk estimates from our meta-analyses were applied to the age categories 30–44 years, 45–59 years and 60–69 years on the basis that this age range was well represented by the studies included in our analyses. In addition, the summary estimate was applied to the 15–29-year age group for all disease end-points except breast cancer. In this case there was sufficient evidence to support differential relative risk estimates for pre-/peri- and postmenopausal women and we classified these groups as 15–44 years, and ≥45 years, respectively.

Reviewing data from two studies on ischaemic heart disease in which older age cohorts were examined (Bijnen et al. 1998; Sesso et al. 2000) we found older adults had around half the excess of the average risk estimate from all other studies combined. This formed the basis of age attenuation estimates. Specifically, 25% of the excess risk was used to estimate risk for the 70–79-year age group and 50% of the excess risk was used for the age group ≥80 years. These algorithms were used to compute age attenuated estimates for all other disease end-points. It is possible that there is no attenuation across age for increased risk of cancer, employing the age attenuation described may have added to the likely underestimation of burden.

### 3.7 Extrapolation of hazard estimates

In general, there was a paucity of data on the effects of physical activity and reduction in risk of disease among populations not of European decent. For ischaemic heart disease and ischaemic stroke, the majority of studies were conducted with men of primarily European descent. For colon and breast cancer the population base was broader but still mostly of North American and European origin. Studies on type II diabetes included data from a much wider range of regions and the reduction in risk was in the same direction across different population groups. Like previous reviews (Powell and Blair 1994), we found no established reasons to suggest that the association between physical inactivity and chronic diseases would differ across diverse populations. Thus, in the absence of evidence to the contrary, we assume that the relative risk estimates for all conditions can be applied across all populations.

### 3.8 Estimated hazards

Where possible, separate relative risks for males and females were used to derive the summary estimates. If studies provided specific risk estimates for various age groups and/or for different domains of activity in addition to an overall summary risk, the estimate across all age groups and/or across all domains was extracted for our analyses (e.g. Morris et al. 1990). If no summary score was presented, the age/domain specific estimates were included as one study in the meta-analysis (e.g. Gillum et al. 1996).

#### *Ischaemic heart disease*

Table 10.19 reports the summary risk estimates from meta-analyses undertaken with and without an adjustment for measurement error. Funnel plots showed little evidence of bias but some heterogeneity in these meta-analyses (Figure 10.24). The regression test showed no evidence of bias ($P = 0.34$).

#### *Ischaemic stroke*

The analyses described above for ischaemic heart disease were repeated for ischaemic stroke and the results are reported in Table 10.20. Funnel plots (Figure 10.25) showed some evidence of heterogeneity and large

**Table 10.19** Summary relative risk estimates for ischaemic heart disease[a] for level 1 (inactive) and level 2 (insufficiently active) exposure, by age and sex

| | *NO adjustment for measurement error*[b] | | *WITH adjustment for measurement error*[b] | |
|---|---|---|---|---|
| *Level 1 (inactive)* | | | | |
| *Age group (years)* | *Males* | *Females* | *Males* | *Females* |
| 0–4 | NA | NA | NA | NA |
| 5–14 | NA | NA | NA | NA |
| 15–29 | 1.47 (1.39–1.56) | 1.47 (1.39–1.56) | 1.71 (1.58–1.85) | 1.71 (1.58–1.85) |
| 30–44 | 1.47 (1.39–1.56) | 1.47 (1.39–1.56) | 1.71 (1.58–1.85) | 1.71 (1.58–1.85) |
| 45–59 | 1.47 (1.39–1.56) | 1.47 (1.39–1.56) | 1.71 (1.58–1.85) | 1.71 (1.58–1.85) |
| 60–69 | 1.47 (1.39–1.56) | 1.47 (1.39–1.56) | 1.71 (1.58–1.85) | 1.71 (1.58–1.85) |
| 70–79 | 1.34 (1.26–1.42) | 1.34 (1.26–1.42) | 1.50 (1.38–1.61) | 1.50 (1.38–1.61) |
| ≥80 | 1.21 (1.14–1.29) | 1.21 (1.14–1.29) | 1.30 (1.21–1.41) | 1.30 (1.21–1.41) |
| *Level 2 (insufficiently active)* | | | | |
| *Age group (years)* | *Males* | *Females* | *Males* | *Females* |
| 0–4 | NA | NA | NA | NA |
| 5–14 | NA | NA | NA | NA |
| 15–29 | 1.31 (1.21–1.41) | 1.31 (1.21–1.41) | 1.44 (1.28–1.62) | 1.44 (1.28–1.62) |
| 30–44 | 1.31 (1.21–1.41) | 1.31 (1.21–1.41) | 1.44 (1.28–1.62) | 1.44 (1.28–1.62) |
| 45–59 | 1.31 (1.21–1.41) | 1.31 (1.21–1.41) | 1.44 (1.28–1.62) | 1.44 (1.28–1.62) |
| 60–69 | 1.31 (1.21–1.41) | 1.31 (1.21–1.41) | 1.44 (1.28–1.62) | 1.44 (1.28–1.62) |
| 70–79 | 1.22 (1.13–1.32) | 1.22 (1.13–1.32) | 1.31 (1.17–1.48) | 1.31 (1.17–1.48) |
| ≥80 | 1.14 (1.06–1.24) | 1.14 (1.06–1.24) | 1.20 (1.07–1.35) | 1.20 (1.07–1.35) |

NA Not applicable.

[a] Incidence and mortality.

[b] Summary risk estimates computed using estimates adjusted for confounding variables (e.g. age, sex) but NOT adjusted for blood pressure and cholesterol. If these were unavailable from any study the available overall adjusted relative risk estimate was used.

bias in these analyses (regression $P$ <0.001). We were unable to account for this bias, however publication bias (i.e. preferential publication and increased citation of studies with significant results) and the restriction to studies published in English may have contributed.

### Breast cancer

Summary risk estimates were computed for pre- and peri-menopausal women combined and for post-menopausal women. These estimates

**Figure 10.24** Funnel plot of studies used in ischaemic heart disease meta-analysis for ischaemic heart disease, level 1 exposure (inactive)

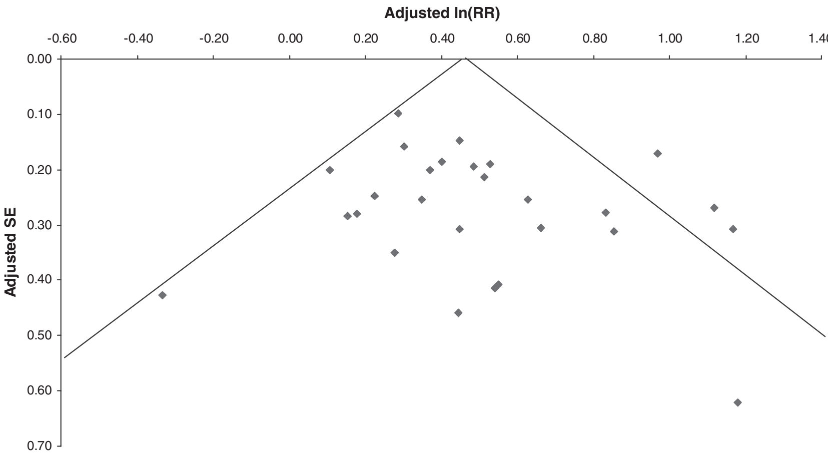



**Figure 10.25** Funnel plot of studies used in ischaemic stroke meta-analysis for ischaemic heart disease, level 1 exposure (inactive)

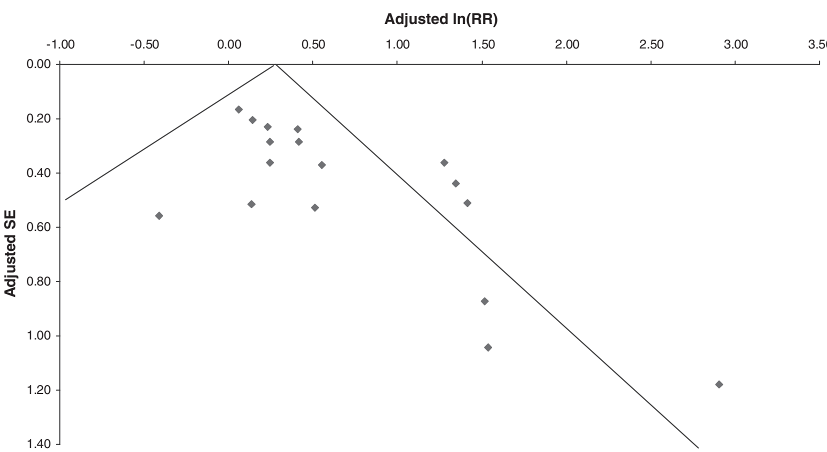


**Table 10.20** Summary relative risk estimates for ischaemic stroke[a] for level 1 (inactive) and level 2 (insufficiently active) exposure, by age and sex

| | *NO adjustment for measurement error*[b] | | *WITH adjustment for measurement error*[b] | |
|---|---|---|---|---|
| *Level 1 (inactive)* | | | | |
| *Age group (years)* | *Males* | *Females* | *Males* | *Females* |
| 0–4 | NA | NA | NA | NA |
| 5–14 | NA | NA | NA | NA |
| 15–29 | 1.39 (1.24–1.56) | 1.39 (1.24–1.56) | 1.53 (1.31–1.79) | 1.53 (1.31–1.79) |
| 30–44 | 1.39 (1.24–1.56) | 1.39 (1.24–1.56) | 1.53 (1.31–1.79) | 1.53 (1.31–1.79) |
| 45–59 | 1.39 (1.24–1.56) | 1.39 (1.24–1.56) | 1.53 (1.31–1.79) | 1.53 (1.31–1.79) |
| 60–69 | 1.39 (1.24–1.56) | 1.39 (1.24–1.56) | 1.53 (1.31–1.79) | 1.53 (1.31–1.79) |
| 70–79 | 1.28 (1.14–1.44) | 1.28 (1.14–1.44) | 1.38 (1.18–1.60) | 1.38 (1.18–1.60) |
| ≥80 | 1.18 (1.05–1.33) | 1.18 (1.05–1.33) | 1.24 (1.06–1.45) | 1.24 (1.06–1.45) |
| *Level 2 (insufficiently active)* | | | | |
| *Age group (years)* | *Males* | *Females* | *Males* | *Females* |
| 0–4 | NA | NA | NA | NA |
| 5–14 | NA | NA | NA | NA |
| 15–29 | 0.97 (0.87–1.15) | 0.97 (0.87–1.15) | 1.10 (0.89–1.37) | 1.10 (0.89–1.37) |
| 30–44 | 0.97 (0.87–1.15) | 0.97 (0.87–1.15) | 1.10 (0.89–1.37) | 1.10 (0.89–1.37) |
| 45–59 | 0.97 (0.87–1.15) | 0.97 (0.87–1.15) | 1.10 (0.89–1.37) | 1.10 (0.89–1.37) |
| 60–69 | 0.97 (0.87–1.15) | 0.97 (0.87–1.15) | 1.10 (0.89–1.37) | 1.10 (0.89–1.37) |
| 70–79 | 0.97 (0.87–1.15) | 0.97 (0.87–1.15) | 1.08 (0.87–1.33) | 1.08 (0.87–1.33) |
| ≥80 | 0.97 (0.87–1.15) | 0.97 (0.87–1.15) | 1.05 (0.85–1.30) | 1.05 (0.85–1.30) |

NA Not applicable.

[a] Incidence and mortality.

[b] Summary risk estimates computed using estimates adjusted for confounding variables (e.g. age, sex) but NOT adjusted for blood pressure and cholesterol. If these were unavailable from any study the available overall adjusted relative risk estimate was used.

were applied to the 15–29- and 30–44-year age groups and those groups of women aged ≥45 years, respectively. The results shown in Table 10.21 indicate a somewhat stronger association between level 1 exposure and breast cancer for post-menopausal women (1.34) compared to pre- and peri-menopausal women (1.25). This relationship is also evident for level 2 exposure. Funnel plot (Figure 10.26) revealed some evidence of bias and heterogeneity. The regression test showed significant bias among studies of post-menopausal women ($P = 0.002$) but not among pre- and peri-menopausal women ($P = 0.23$).

**Table 10.21** Summary relative risk estimates for breast cancer[a] for level 1 (inactive) and level 2 (insufficiently active) exposure, by age and sex

| | *Adjusted for confounding variables but NO adjustment for measurement error* | | *Adjusted for confounding variables WITH adjustment for measurement error* | |
|---|---|---|---|---|
| *Level 1 exposure (inactive)* | | | | |
| *Age group (years)* | *Males* | *Females* | *Males* | *Females* |
| 0–4 | NA | NA | NA | NA |
| 5–14 | NA | NA | NA | NA |
| 15–29 | NA | 1.13 (1.04–1.22) | NA | 1.25 (1.20–1.30) |
| 30–44 | NA | 1.13 (1.04–1.22) | NA | 1.25 (1.20–1.30) |
| 45–59 | NA | 1.13 (1.04–1.22) | NA | 1.34 (1.29–1.39) |
| 60–69 | NA | 1.13 (1.04–1.22) | NA | 1.34 (1.29–1.39) |
| 70–79 | NA | 1.09 (1.01–1.18) | NA | 1.25 (1.21–1.30) |
| ≥80 | NA | 1.06 (0.98–1.15) | NA | 1.16 (1.11–1.20) |
| *Level 2 exposure (insufficiently active)* | | | | |
| *Age group (years)* | *Males* | *Females* | *Males* | *Females* |
| 0–4 | NA | NA | NA | NA |
| 5–14 | NA | NA | NA | NA |
| 15–29 | NA | 1.09 (1.03–1.16) | NA | 1.13 (1.04–1.22) |
| 30–44 | NA | 1.09 (1.03–1.16) | NA | 1.13 (1.04–1.22) |
| 45–59 | NA | 1.09 (1.03–1.16) | NA | 1.13 (1.04–1.22) |
| 60–69 | NA | 1.09 (1.03–1.16) | NA | 1.13 (1.04–1.22) |
| 70–79 | NA | 1.07 (1.01–1.13) | NA | 1.09 (1.01–1.18) |
| ≥80 | NA | 1.04 (0.98–1.11) | NA | 1.06 (0.98–1.15) |

NA Not applicable.

[a] Incidence and mortality.

### Colon cancer

Table 10.22 reports the results of risk associated with colon cancer for men and women. Separate analyses by sex were conducted but showed a non-significant difference, thus pooled estimates are provided (data not shown). Funnel plots showed some evidence of bias but little heterogeneity (see Figure 10.27), however the regression test revealed a significant bias ($P$ <0.001). This bias would appear to be attributable to the inclusion of three studies which each had relatively large estimates of risk and small standard errors (Gerhardsson et al. 1988; Longnecker et al. 1995; Tang et al. 1999). Excluding these studies resulted in a regression test p-value of 0.30 and had no effect on the summary risk estimates.

**Figure 10.26** Funnel plot of studies used in breast cancer meta-analysis for ischaemic heart disease, level 1 exposure (inactive)

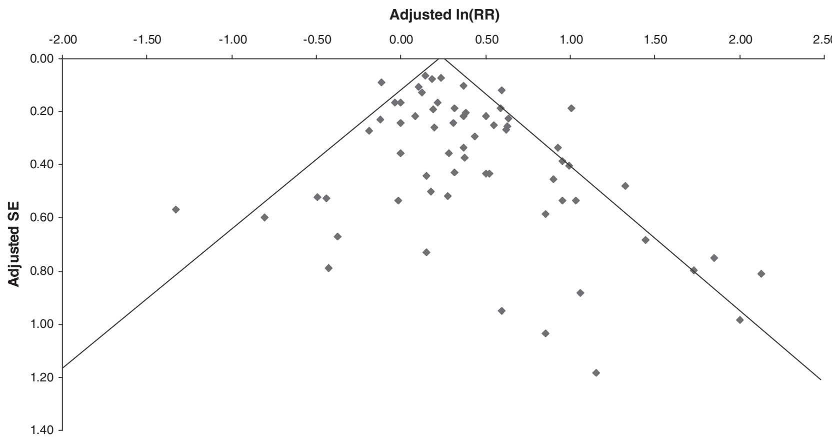
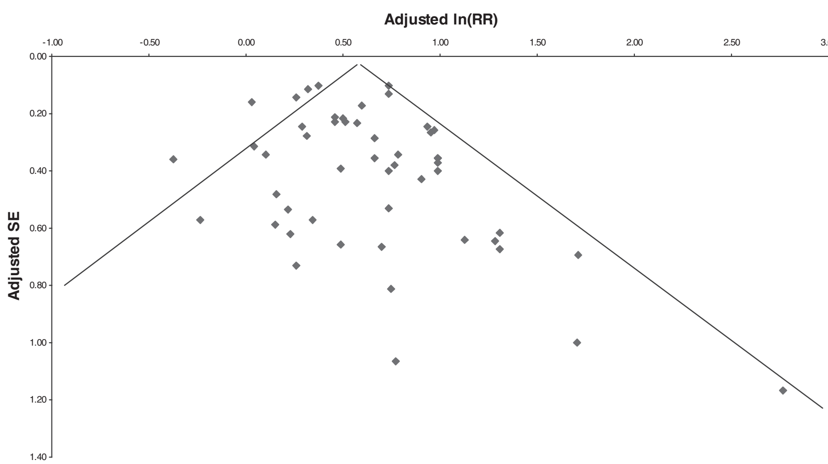



**Figure 10.27** Funnel plot of studies used in colon cancer meta-analysis for ischaemic heart disease, level 1 exposure (inactive)




*Type II diabetes*

The risk of type II diabetes associated with level 1 exposure was 1.45 and 1.31, with and without the adjustment for measurement error, respectively (see Table 10.23). Level 2 exposure was associated with a relative risk of 1.24 (with measurement adjustment) and 1.17 (without

**Table 10.22** Summary relative risk estimates for colon cancer[a] for level 1 (inactive) and level 2 (insufficiently active) exposure, by age and sex

| | *Adjusted for confounding variables but NO adjustment for measurement error* | | *Adjusted for confounding variables WITH adjustment for measurement error* | |
|---|---|---|---|---|
| *Level 1 exposure (inactive)* | | | | |
| *Age group (years)* | *Males* | *Females* | *Males* | *Females* |
| 0–4 | NA | NA | NA | NA |
| 5–14 | NA | NA | NA | NA |
| 15–29 | 1.43 (1.38–1.49) | 1.43 (1.38–1.49) | 1.68 (1.55–1.82) | 1.68 (1.55–1.82) |
| 30–44 | 1.43 (1.38–1.49) | 1.43 (1.38–1.49) | 1.68 (1.55–1.82) | 1.68 (1.55–1.82) |
| 45–59 | 1.43 (1.38–1.49) | 1.43 (1.38–1.49) | 1.68 (1.55–1.82) | 1.68 (1.55–1.82) |
| 60–69 | 1.43 (1.38–1.49) | 1.43 (1.38–1.49) | 1.68 (1.55–1.82) | 1.68 (1.55–1.82) |
| 70–79 | 1.31 (1.26–1.36) | 1.31 (1.26–1.36) | 1.48 (1.36–1.60) | 1.48 (1.36–1.60) |
| ≥80 | 1.20 (1.15–1.24) | 1.20 (1.15–1.24) | 1.30 (1.20–1.40) | 1.30 (1.20–1.40) |
| *Level 2 exposure (insufficiently active)* | | | | |
| *Age group (years)* | *Males* | *Females* | *Males* | *Females* |
| 0–4 | NA | NA | NA | NA |
| 5–14 | NA | NA | NA | NA |
| 15–29 | 1.11 (1.03–1.20) | 1.11 (1.03–1.20) | 1.18 (1.05–1.33) | 1.18 (1.05–1.33) |
| 30–44 | 1.11 (1.03–1.20) | 1.11 (1.03–1.20) | 1.18 (1.05–1.33) | 1.18 (1.05–1.33) |
| 45–59 | 1.11 (1.03–1.20) | 1.11 (1.03–1.20) | 1.18 (1.05–1.33) | 1.18 (1.05–1.33) |
| 60–69 | 1.11 (1.03–1.20) | 1.11 (1.03–1.20) | 1.18 (1.05–1.33) | 1.18 (1.05–1.33) |
| 70–79 | 1.08 (1.00–1.17) | 1.08 (1.00–1.17) | 1.13 (1.01–1.27) | 1.13 (1.01–1.27) |
| ≥80 | 1.05 (0.97–1.14) | 1.05 (0.97–1.14) | 1.08 (0.97–1.22) | 1.08 (0.97–1.22) |

NA Not applicable.

[a] Incidence and mortality.

measurement adjustment). Age attenuation was applied to the age groups of 70–79 years and ≥80 years.

The funnel plot showed no evidence of heterogeneity (Figure 10.28) but strong evidence of bias for these analyses (regression test $P$ <0.001). We were unable to account for this bias, however it is possible that publication bias may have contributed.

### Discussion of relative risk estimates

Overall the results from our set of meta-analyses are similar to previous reports. For instance, the summary estimate of the independent effect of inactivity (1.38) is similar to previous findings of Eaton (1992) and the

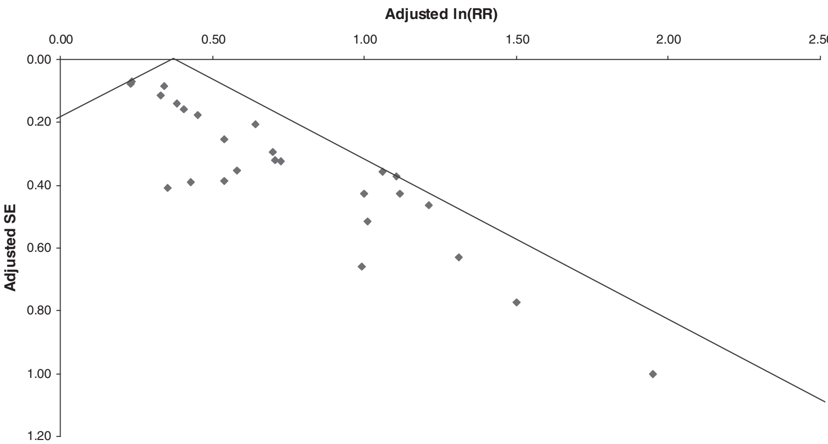
**Table 10.23** Summary relative risk estimates for type II diabetes for level 1 (inactive) and level 2 (insufficiently active) exposure, by age and sex

| | *Adjusted for confounding variables but NO adjustment for measurement error* | | *Adjusted for confounding variables WITH adjustment for measurement error* | |
|---|---|---|---|---|
| *Level 1 exposure (inactive)* | | | | |
| *Age group (years)* | *Males* | *Females* | *Males* | *Females* |
| 0–4 | NA | NA | NA | NA |
| 5–14 | NA | NA | NA | NA |
| 15–29 | 1.31 (1.24–1.39) | 1.31 (1.24–1.39) | 1.45 (1.37–1.54) | 1.45 (1.37–1.54) |
| 30–44 | 1.31 (1.24–1.39) | 1.31 (1.24–1.39) | 1.45 (1.37–1.54) | 1.45 (1.37–1.54) |
| 45–59 | 1.31 (1.24–1.39) | 1.31 (1.24–1.39) | 1.45 (1.37–1.54) | 1.45 (1.37–1.54) |
| 60–69 | 1.31 (1.24–1.39) | 1.31 (1.24–1.39) | 1.45 (1.37–1.54) | 1.45 (1.37–1.54) |
| 70–79 | 1.22 (1.15–1.30) | 1.22 (1.15–1.30) | 1.32 (1.25–1.40) | 1.32 (1.25–1.40) |
| ≥80 | 1.14 (1.08–1.21) | 1.14 (1.08–1.21) | 1.20 (1.14–1.28) | 1.20 (1.14–1.28) |
| *Level 2 exposure (insufficiently active)* | | | | |
| *Age group (years)* | *Males* | *Females* | *Males* | *Females* |
| 0–4 | NA | NA | NA | NA |
| 5–14 | NA | NA | NA | NA |
| 15–29 | 1.17 (1.08–1.27) | 1.17 (1.08–1.27) | 1.24 (1.10–1.39) | 1.24 (1.10–1.39) |
| 30–44 | 1.17 (1.08–1.27) | 1.17 (1.08–1.27) | 1.24 (1.10–1.39) | 1.24 (1.10–1.39) |
| 45–59 | 1.17 (1.08–1.27) | 1.17 (1.08–1.27) | 1.24 (1.10–1.39) | 1.24 (1.10–1.39) |
| 60–69 | 1.17 (1.08–1.27) | 1.17 (1.08–1.27) | 1.24 (1.10–1.39) | 1.24 (1.10–1.39) |
| 70–79 | 1.12 (1.04–1.22) | 1.12 (1.04–1.22) | 1.18 (1.04–1.32) | 1.18 (1.04–1.32) |
| ≥80 | 1.08 (1.00–1.17) | 1.08 (1.00–1.17) | 1.11 (0.99–1.25) | 1.11 (0.99–1.25) |

NA Not applicable.

recent findings reported by Williams (2001). Eaton (1992) found an association between physical inactivity and ischaemic heart disease of 1.37 (1.27–1.48) from a set of 14 studies that assessed discretionary time and/or well-defined occupational physical activity, with ischaemic heart disease mortality or morbidity as disease end-points. More recently, Williams (2001) pooled results from 16 cohorts with measures of discretionary-time physical activity or "all physical activity" and ischaemic heart disease end-points. The author reported pooled relative risk estimates against percentiles of activity and showed relative risks of between 0.65–0.75 for the 70th percentile and above of activity compared with the referent group of zero activity. Inverting his result to allow comparison with this study produced a relative risk of about 1.4.

**Figure 10.28** Funnel plot of studies used in type II diabetes meta-analysis for ischaemic heart disease, level 1 exposure (inactive)




Our results are also consistent with earlier reviews undertaken by Powell et al. (1987) and Berlin and Colditz (1990) when the differences in protocols are reviewed. Powell et al. (1987) pooled 47 studies with diverse methodological properties and included studies with exposure of either fitness or physical activity. Their qualitative summary estimate of relative risk was 1.9 but the authors noted the magnitude of this association ranged from 1.5–2.4. Berlin and Colditz (1990) replicated the work of Powell et al. with the addition of any subsequent published work, and reported several estimates of relative risk specific to occupational physical activity and non-occupational activity, and for separate cardiovascular disease outcomes. Also, they undertook separate analyses for studies with two and with three levels of exposure. Using only those studies included by Powell et al., they computed a summary estimate of risk for discretionary-time inactivity and ischaemic heart disease (morbidity) of 1.6 with a confidence interval of 1.3–1.8 (see published paper Table 4, analysis B) (Berlin and Colditz 1990). This did not change substantially when additional studies were added (RR=1.5, 95% CI 1.4–1.7, see published paper Table 5, analysis B).

Berlin and Colditz refined their analyses by separating studies based on epidemiological criteria and classified studies as "satisfactory" and "unsatisfactory". Including only the former studies, relative risk estimates ranged from 1.3 (0.7–2.6) to 1.9 (1.0–3.6) for ischaemic heart disease mortality (see published paper Table 6). Thus, comparing our results with the intricate set of analyses of Berlin and Colditz and other previous work of Powell et al. (1987), and Eaton (1992) revealed our results are similar and well within the range of published confidence limits.

We found a weaker relationship for the effect of physical activity on ischaemic stroke than on ischaemic heart disease, the relative risk estimate for the inactive group being 1.53. The existence of a dose–response relationship between physical activity and stroke is not yet established (Kohl 2001) and there is no evidence of a dose–response effect seen in this study, with the relative risk of the insufficiently active group being no different from 1.

The relative risk of physical inactivity associated with developing type II diabetes was 1.45 (1.37–1.54) and this was applied to men and women. Previous studies have reported a differential protective effect across sex, however we found only modest evidence for level 1 exposure and no evidence for level 2 exposure. Any apparent difference may have been due to the large degree of heterogeneity among studies. A dose–response relationship across levels of exposure was observed and this is consistent with a recent review of the benefits of physical activity in preventing or delaying the development of diabetes (Kelley and Goodpaster 2001).

The relative risk associated with colon cancer was 1.68 (1.55–1.82) for inactive adults compared with those who are reaching recommended levels of activity. The insufficiently active group had a lower relative risk of 1.18 (1.05–1.33) compared to the referent group. These results indicate a dose–response relationship across exposure and this is consistent with previous research (Thune and Furberg 2001). No previous quantitative meta-analyses have been undertaken on physical inactivity and colon cancer, although the recent review by Thune and Furberg (2001) concluded that the majority of studies showed an independent protective effect ranging in magnitude of between 10% and 70% (2001).

We found the relative risks associated with breast cancer were 1.25 (1.20–1.30) for women aged 15–44 years and 1.34 (1.29–1.39) for women aged 45–69 years. These results are consistent with a previously published qualitative review that showed a 30% reduction in risk of breast cancer among pre-, peri- and post-menopausal women, with a graded dose- response seen in around half of the studies reviewed (Thune and Furberg 2001). Evidence of a dose–response effect was observed with the relative risk of 1.13 (1.04–1.22) associated with the insufficiently active group.

In summary, our estimates of risk of ischaemic heart disease are consistent with previous research, given a careful inspection of the study inclusion criteria and treatment of the data. There are less data by which to compare our results on ischaemic stroke and no previous quantitative reviews addressing type II diabetes and breast and colon cancers. Across all health outcomes, except ischaemic stroke, a dose–response relationship was observed, with the most inactive (level 1 exposure) associated with having the greatest risk. There is considerable heterogeneity across studies aimed at answering apparently similar questions. This is a notable limitation to conducting meta-analyses. This field of research would benefit from improved measures of exposure; and greater consistency in the reporting of results between studies would advance this field.

## 3.9 Risk reversibility and temporal aspects of the risk factor–disease relationship

There is little direct evidence on risk reversibility associated with increases in levels of physical activity. This is primarily due to the lack of randomized controlled trials and the fact that a long period between exposure to physical inactivity and disease outcomes is required for assessment. Further, the few data that are available mostly relate to risk reduction in all-cause mortality and ischaemic heart disease and predominantly among white men from middle to upper socioeconomic groups. Despite these limitations, we reviewed the available literature and attempted to estimate the magnitude and time lag associated with change in level of activity and change in risk. Our conclusions for each health outcome are summarized below.

### *Ischaemic heart disease and ischaemic stroke*

Increase in levels of physical activity can reduce the risk of ischaemic heart disease (Paffenbarger et al. 1994). Among Harvard alumni, physically inactive men who started a moderate–vigorous physical activity routine reduced risk of ischaemic heart disease mortality by 41% compared with men who remained inactive (Paffenbarger et al. 1993). This is consistent with findings on the benefits of changes in cardiorespiratory fitness, which although not included in this review may help inform the potential nature of risk reversibility due to physical inactivity (Blair et al. 1995). Blair et al. (1995) reported a reduction in risk of ischaemic heart disease due to improvements in cardiorespiratory fitness. They found that men classified as unfit at their initial examination and fit at their subsequent examination had a 44% reduction in risk of ischaemic heart disease mortality than did men who were unfit at both examinations (Blair et al. 1995). Furthermore, these associations were independent of other potentially confounding factors (e.g. smoking, BMI, systolic blood pressure, cholesterol) (Blair et al. 1995, 1996). Moreover, there is evidence to suggest that recent participation in physical activity, rather than activity performed in the past, is required for reduction in risk of ischaemic heart disease (Paffenbarger et al. 1978).

Although there is limited empirical support, there are indications that reversibility for ischaemic heart disease could be complete, and could occur within a relatively short period of time following reversal of exposure, perhaps as short as several months or up to two years. This assumption is based on the available evidence pertaining to changes in physical inactivity, indirect evidence from studies using fitness parameters, and known acute effects of physical activity on elements of the physiological pathways which reduce cardiovascular risk.

There is little evidence to guide the estimates of risk reversibility for ischaemic stroke following changes in exposure to physical inactivity. As the biological pathways are considered to be the same as those for ischaemic heart disease, it is possible that there may be a similar relationship for a reduction in risk.

*BREAST CANCER AND COLON CANCER*

There are no data to help quantify what degree of risk reduction may occur over what time frame for breast cancer. The paucity of data on physical activity and risk reduction required us to use indicative information on which to base such estimates. Studies on the cessation of postmenopausal hormone replacement therapy and breast cancer rates provide indirect estimates, as the biological pathways (i.e. through hormone levels, as described in section 1) are considered to be similar to that assumed for physical activity's impact on breast cancer.

Major reviews of the epidemiological evidence suggest complete reversibility. That is, women who stop postmenopausal hormone replacement therapy generally revert to the same breast cancer rates as women who had never had hormone replacement therapy, over a period of two to five years (Collaborative Group on Hormonal Factors in Breast Cancer 1997; La Vecchia et al. 2001). There is, however, debate on the biological plausibility and mechanisms of this observed reduction in risk (Bieber and Barnes 2001).

Again there are few data to indicate what the magnitude of risk reduction may be over time for colon cancer. Lee et al. (1991) suggested that although a lifetime or at least consistent participation during adulthood in physical activity is required for greatest protection from risk of colon cancer, some reduction (13% over 11–15 years) is seen in men who become active after being inactive.

*TYPE II DIABETES*

There are two sources of information to help with risk reversibility for type II diabetes. Data from the Nurses' Health Study show that women who increased their physical activity levels over six years experienced 29% lower rates of type II diabetes than those who remained inactive over the same period (RR = 0.71) (Hu et al. 1999). However, women who were active at the beginning and remained active over the six years still had lower rates of type II diabetes than those who became active (RR = 0.59). Recently, the Diabetes Prevention Program Research Group (2002) showed that, among people who had impaired glucose tolerance, a lifestyle intervention combining moderate amounts of physical activity with a controlled diet resulted in a 58% reduction in the incidence of type II diabetes over 2 to 5 years. Since this risk reduction resulted from a combined lifestyle intervention with a population already at increased risk, the effect of only changes in physical activity in the general population is assumed to be less. These estimates suggest a risk reversibility of 25% over five years for sedentary adults becoming sufficiently active and 35% over four years for insufficiently active adults becoming sufficiently active.

## 4. Burden of disease attributable to physical inactivity

The fraction of burden (mortality and morbidity combined) attributable to physical inactivity for each disease end-point is shown in Figure 10.29. Globally physical inactivity contributed to an estimated 22% of ischaemic heart disease, 11% of ischaemic stroke, 14% of type II diabetes, 16% of colon cancer and 10% of breast cancer. The results show small differences between males and females, due in part to differences in the level of exposure and to the different distribution of events between the sexes. There were small, non-significant differences in the attributable fractions across subregions (data not shown). For ischaemic heart disease the subregional differences ranged from 21% (SEAR-D, EMR-D and WPR-B) to 23% (AMR-B, EUR-C and WPR-A). A slightly wider range was seen for ischaemic stroke 9% (AFR-D) to 14% (EUR-C).

The number of deaths and number of DALYs were computed for each disease outcome (Figures 10.30 and 10.31, respectively). Over one

**Figure 10.29** Attributable burden of disease due to physical inactivity for ischaemic heart disease, ischaemic stroke, type II diabetes, colon cancer and breast cancer

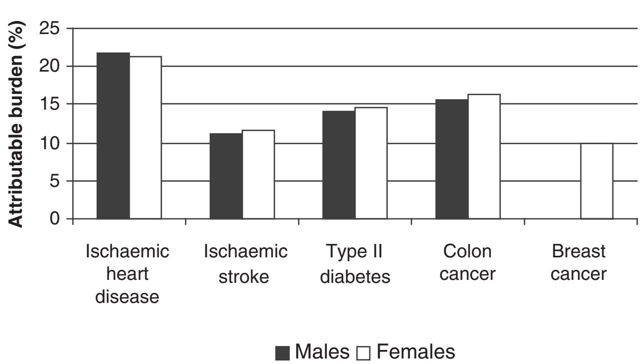


**Figure 10.30** Attributable mortality due to physical inactivity for ischaemic heart disease, ischaemic stroke, type II diabetes, colon cancer and breast cancer

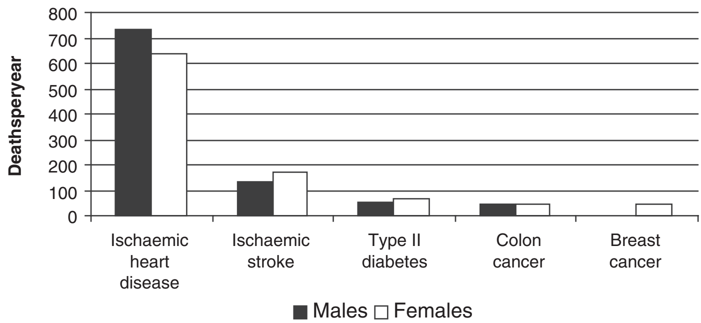
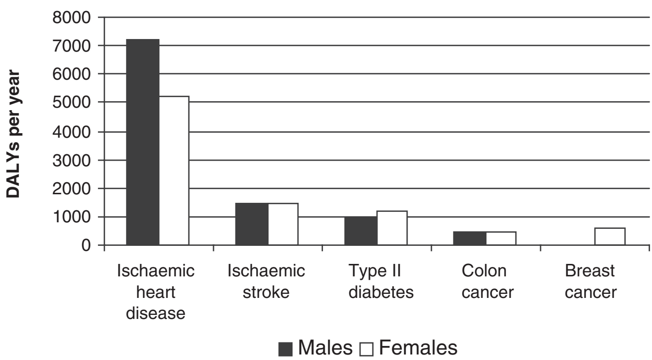



**Figure 10.31** Attributable DALYs due to physical inactivity for ischaemic heart disease, ischaemic stroke, type II diabetes, colon cancer and breast cancer




million deaths due to ischaemic heart disease were attributable to physical inactivity (730 000 males and 634 000 females). Another 308 000 deaths from ischaemic stroke were also attributable to inactive and insufficiently active lifestyles. Combined with deaths from type II diabetes (116 000), colon cancer (90 000) and breast cancer (45 000) a total of 1.92 million deaths could be prevented from increasing levels of physical activity (Figure 10.30). Similarly inactive lifestyles contributed to a loss of 19 million DALYs worldwide.

## 5. Discussion

The attributable fraction for ischaemic heart disease morbidity and mortality (22%) is slightly lower than previous estimates that range from 23% (Hahn et al. 1990) to 35% (Powell and Blair 1994). This variation is explained by differences in the estimates used for prevalence and relative risk. Previous attempts have used rounded estimates of risk (1.9) (Powell and Blair 1994). We estimated relative risks that are consistent but marginally lower than previous reports because we only accepted data from studies reporting an exposure of physical activity not physical fitness; risk of exposure was computed relative to the current public health recommendations not a referent group of "high level of activity" or "vigorously active"; an adjustment for attenuation of risk over age was included; and, perhaps most importantly, we used a trichotomous not continuous measure of exposure. We acknowledge that no attempt was made to account for the additional benefit associated with being highly active and/or engaging in activities of vigorous intensity.

Furthermore, past estimates of exposure have been based on only one domain, namely discretionary time. Single domain estimates will overestimate exposure by not including activity undertaken in other domains. Another important difference with previous estimates is in the number of categorical levels used in the analyses. We created a trichotomous measure; in contrast previous work had used four levels of exposure (Powell and Blair 1994). Estimates of level 2 exposure should be interpreted with great caution. Available data were the most difficult to compare and we acknowledge our assumptions will inevitably include some misclassification. Our global estimate of insufficiently active was 41%, although data show that in different countries it can range from 20% to 70%. For both level 1 and level 2 there is greatest uncertainty around prevalence estimates for Africa, Asia and the Eastern Mediterranean and across all subregions for adults aged >60 years. There is a corresponding high level of uncertainty around the estimates of disease burden for these subregions and age groups. A difference of ±10% in prevalence estimates would make a considerable difference in the estimated magnitude of the disease burden.

Given the noted differences between our input variables and those used in previous reports, our global estimates of attributable fraction appear consistent, but we suggest that they too are likely to underestimate the true burden due to inactive lifestyles. Moreover, a number of the limitations combine to make it more difficult to compare with other continuously measured risk factors such as blood pressure and cholesterol.

In summary, the multiple model of exposure provided a useful platform for these analyses of attributable burden but recent, comparable country-level data on inactivity would be far more preferable. This would require, however, having more countries systematically collect data on the distribution of physical inactivity. Well developed, culturally appropriate measurement instruments should be used to collect comparable data. While there are examples of progress in this area (Craig et al. 2003), with few exceptions, instruments to assess exposure across the diverse cultures of Africa, Asia and the Eastern Mediterranean have yet to be well tested or widely used.

Emerging evidence is pointing towards the important role of physical activity in avoiding outcomes (e.g. falls, poor mental health) as well as other disease end-points (e.g. osteoarthritis and osteoporosis) that did not meet our inclusion criteria. Future replications of this work should review the evidence to ensure a complete a picture as possible is obtained on the burden attributable to inactivity. Across these outcomes as well as those included, the exact nature of the dose–response relationship across all disease end-points is not well defined. Moreover, the heterogeneity across studies is notable and represents a limitation to conducting meta-analyses in this field. Researchers are encouraged to pursue this research agenda systematically to maximize the expedient pooling of data and furthering of our knowledge.

Physically inactive lifestyles account for 3.3% of deaths and morbidity worldwide. Successful promotion of more active lifestyles would prevent at least 2 million premature deaths and almost 20 million DALYs worldwide. Success in prevention requires greater commitment through policy development and resource allocation at the national and local level. Diverse challenges face developed and developing countries as they consider the current and future rapid changes in patterns of activity by domain.

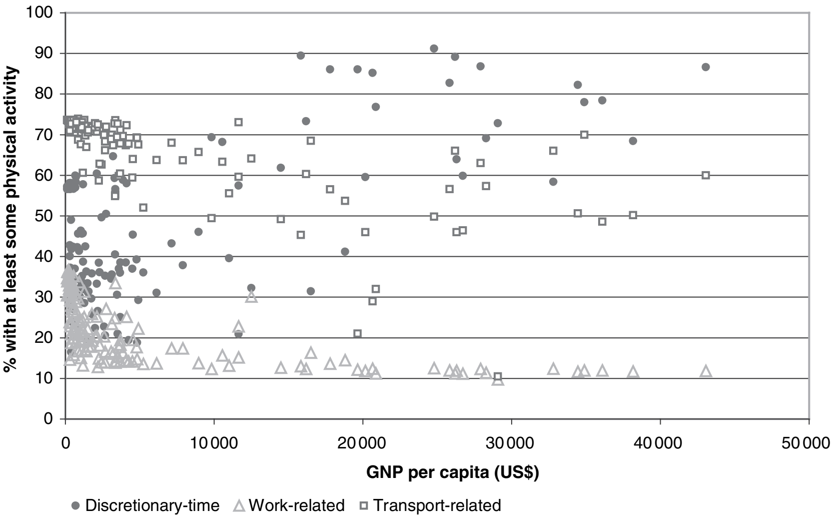
## 6. Projected estimates of future exposure

Calculation of the avoidable burden of disease requires predicated estimates of exposure in the future. Estimates are usually based on trends and patterns seen over past years adjusted based on assumptions and models of factors likely to influence exposure in the future. We looked for data on patterns of activity over time for predicting level 1 and level 2 exposure in 2010, 2020 and 2030. Our search found few trend data and those available were mostly from developed countries and had similar limitations regarding their comparability as previously discussed.

### 6.1 Methods

In the absence of data on trends to guide our calculations of future exposure we considered the factors that might influence inactivity in the next 30 years. Considering each domain separately and in combination, we proposed that economic development was a central factor to changes in the level of physical activity undertaken in the work place, at home, through transportation and in leisure time. As economies develop, new mechanical, computer and biological technologies will reduce the

**Figure 10.32** Predicted[a] estimates of physical activity for 145 countries in 2000, by domain and GNP per capita

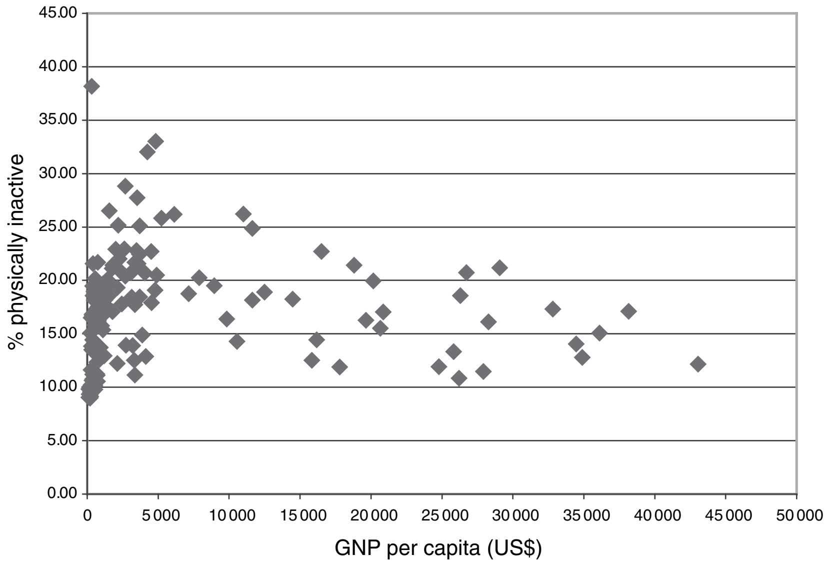



[a] Actual physical activity estimates for countries were used when available.

demand for physical tasks in the work place as well as drive the shift in employment from agriculture to manufacturing and service industries. Both factors will result in lower levels of physical activity in the occupational domain. Furthermore, as economies develop and individuals have higher incomes, there will be a shift in travel behaviour, specifically walking and cycling will decrease in favour of modes of personal transportation (motor vehicle) and to a lesser extent public transit. Discretionary time is likely to increase as economies develop and there is a higher level of wealth. While there is more time for discretionary physical activity there also will be more alternative options, many of which will require low levels of physical activity, for example, computer-based entertainment and television. Figure 10.32 shows our predicted estimates for physical activity in 2000 by domain and GNP.

We also considered whether the changes in physical activity within each domain over time could have a lag effect, such that increases in available leisure time would result some time after the shifts in the work place and changes in transportation. However, we had insufficient data to model future change in each domain separately or to explore our hypothetical time lag. Instead we used the net effect or the summary estimate of physical inactivity and GNP (shown in Figure 10.33) to model the association based on current (year 2000) levels. We then used dif-

**Figure 10.33** Per cent physically inactive (level 1 exposure) for 145 countries by GNP per capita




ferentiation to compute the change in inactivity associated with a change in GNP over time and predicted estimates of GNP to solve the equation and compute estimates for physical inactivity in 2010, 2020 and 2030. This method is described in detail below.

*METHODS FOR THE PROJECTION OF FUTURE ESTIMATES OF LEVEL 1 EXPOSURE*

Prevalence of inactivity was related to GNP per capita for each country and prevalence of malnutrition (at the regional level rather than country level) as below. Malnutrition (as measured by childhood underweight) was included in the model along with GNP because preliminary regression analyses using per cent childhood mortality improved the model fit substantially for developing countries. However, future predictions for child mortality were not available therefore malnutrition was used as a proxy measure. Because country level estimates of malnutrition also did not exist, predicted estimates at the regional level were used (see chapter 2).

$$\log(\%\ \text{Inactivity}_{2000}) = B_1(\text{GNP per capita}_{2000}) + B_2(\%\ \text{malnutrition}_{2000})$$

Linear regression was used to estimate $B_1$ and $B_2$. The relationship between GNP per capita in 2000 and the prevalence of inactivity for

**Table 10.24** Mean (range) GNP per capita and % malnourished for years 2000 and 2030

| World Bank income classification | GNP per capita (US$ 1000) | | % children malnourished | |
|---|---|---|---|---|
| | 2000 | 2030 | 2000 | 2030 |
| Low/Middle income | 3.6 (0.5–14.9) | 8.2 (0.9–53.8) | 18.8 (2.3–45.9) | 18.4 (0.0–50.7) |
| High income | 22.7 (12.3–33.6) | 59.6 (31.9–105.9) | 3.1 (2.3–8.1) | 0.0 (0.0–0.5) |

2000 showed that inactivity increased with GNP per capita when GNP was less than US$ 5000 and decreased when GNP was greater than US$ 5000 (Figure 10.33). Therefore, we divided countries into two groups using World Bank income classification: a low/middle-income group, and high-income group (including Organisation for Economic Co-operation and Development [OECD] and non-OECD countries). The two groups were modelled separately to give two sets of parameter estimates for $B_1$ and $B_2$. Inactivity (%) was log-transformed and all variables were centred to reduce collinearity and to set the regression intercepts to zero by using mean % inactivity equal to zero. Change in physical inactivity over time was computed using predicted changes in GNP per capita (from World Bank estimates) and predicted change in malnutrition (World Bank 1999; chapter 2).

The assumption that the relationship seen in year 2000 would continue to characterize countries in year 2030 is examined in Table 10.24. Mean GNP increases in both groups between year 2000 and 2030 with a considerable increase in the ranges with only a small overlap between groups. Malnutrition, predicted at the regional level and aggregated to create a group estimate showed only a very small decrease over time in the low/middle-income group reflecting the worsening conditions predicted for some regions (e.g. Africa). For high-income countries malnutrition is predicted to approach zero by 2030 (chapter 2).

*Methods for the projection of future estimates of level 2 exposure*

Age by sex estimates of level 2 exposure (insufficiently active) were computed by holding constant our predicted values for year 2000 and applying these uniformly for 2010, 2020 and 2030. We chose this simple approach based on evidence that changes in the population distribution of physical (in)activity occur between levels of both inactive and insufficiently active, as well as between insufficiently active and sufficient (level 3 unexposed). We had no data on which to estimate the magnitude of the shift between level 2 and level 3. Thus, our predicted values of level 2 exposure are based on the assumption that the changes calculated for level 1 (predicted based on changes in economic development as described above) are equal to the change from level 2 to level 3—the net result of which is that level 2 estimates remain unchanged over time.

This approach is clearly limited but without more data from different populations on both current trends and patterns over time it was the only feasible approach.

### 6.2 Results

The parameter estimates for the model used to estimate future level 1 exposure show the different relationship between physical inactivity estimates in 2000 and GNP per capita and % malnutrition for each group (see Figure 10.33). Final age by sex estimates for 14 subregions for 2010, 2020 and 2030 are shown in Tables 10.25, 10.26 and 10.27, respectively. These data indicate an increasing physical inactivity in all subregions, for males and females and across all age groups. The magnitude of increase in level 1 exposure was of the order of 3–4%. We did not model any change in level 2 exposure. Recent evidence suggests these data are likely to grossly underestimate change in exposure. Between 1999 and 2002, Western Australia experienced a 4% decline in the proportion of the population meeting recommended levels of physical activity (McCormack et al. 2003). These data may be more indicative of the possible magnitude of negative change to expect in developed market economies in coming years if no action is undertaken. Taken in combination with the changing patterns of lifestyle people will experience in developing economies, the future burden of disease attributable to inactivity may be considerable.

**Table 10.25** Projected estimates (%) of physical inactivity in year 2010

| | | *Males* | | | | | | *Females* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Subregion* | *Exposure level* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* |
| AFR-D | Inactive | 11 | 13 | 14 | 16 | 18 | 19 | 13 | 12 | 13 | 16 | 19 | 20 |
| | Insufficient | 48 | 48 | 48 | 46 | 44 | 43 | 45 | 52 | 51 | 48 | 46 | 45 |
| | Recommended | 41 | 39 | 38 | 38 | 38 | 38 | 42 | 36 | 36 | 36 | 35 | 35 |
| AFR-E | Inactive | 9 | 12 | 12 | 15 | 16 | 17 | 12 | 11 | 11 | 14 | 16 | 16 |
| | Insufficient | 50 | 51 | 50 | 49 | 47 | 46 | 47 | 56 | 55 | 51 | 50 | 50 |
| | Recommended | 41 | 37 | 38 | 36 | 37 | 37 | 41 | 33 | 34 | 35 | 34 | 34 |
| AMR-A | Inactive | 17 | 19 | 20 | 21 | 22 | 32 | 22 | 23 | 21 | 27 | 31 | 41 |
| | Insufficient | 44 | 47 | 44 | 40 | 40 | 35 | 36 | 41 | 40 | 38 | 36 | 31 |
| | Recommended | 39 | 34 | 36 | 39 | 38 | 33 | 42 | 36 | 39 | 35 | 33 | 28 |
| AMR-B | Inactive | 17 | 18 | 20 | 23 | 26 | 29 | 23 | 28 | 28 | 38 | 40 | 42 |
| | Insufficient | 42 | 44 | 41 | 39 | 36 | 35 | 33 | 32 | 31 | 30 | 30 | 29 |
| | Recommended | 41 | 38 | 39 | 38 | 38 | 36 | 44 | 40 | 41 | 32 | 30 | 29 |
| AMR-D | Inactive | 17 | 19 | 19 | 23 | 28 | 30 | 22 | 26 | 30 | 40 | 46 | 48 |
| | Insufficient | 38 | 38 | 33 | 32 | 30 | 29 | 28 | 26 | 24 | 24 | 22 | 22 |
| | Recommended | 45 | 43 | 48 | 45 | 42 | 41 | 50 | 48 | 46 | 36 | 32 | 30 |
| EMR-B | Inactive | 16 | 19 | 19 | 22 | 25 | 27 | 19 | 21 | 21 | 25 | 31 | 33 |
| | Insufficient | 41 | 39 | 38 | 36 | 32 | 32 | 36 | 36 | 35 | 32 | 31 | 30 |
| | Recommended | 43 | 42 | 43 | 42 | 43 | 41 | 45 | 43 | 44 | 43 | 38 | 37 |
| EMR-D | Inactive | 15 | 18 | 19 | 21 | 23 | 26 | 18 | 20 | 20 | 23 | 30 | 31 |
| | Insufficient | 42 | 38 | 36 | 35 | 32 | 31 | 36 | 36 | 35 | 32 | 31 | 30 |
| | Recommended | 43 | 44 | 45 | 44 | 45 | 43 | 46 | 44 | 45 | 45 | 39 | 39 |

*continued*

**Table 10.25** Projected estimates (%) of physical inactivity in year 2010 (*continued*)

| | | *Males* | | | | | | *Females* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Subregion* | *Exposure level* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* |
| EUR-A | Inactive | 14 | 15 | 16 | 19 | 21 | 22 | 17 | 19 | 19 | 23 | 25 | 29 |
| | Insufficient | 52 | 57 | 55 | 52 | 50 | 47 | 47 | 51 | 51 | 45 | 45 | 42 |
| | Recommended | 34 | 28 | 29 | 29 | 29 | 31 | 36 | 30 | 30 | 32 | 30 | 29 |
| EUR-B | Inactive | 15 | 19 | 20 | 22 | 26 | 28 | 19 | 40 | 38 | 36 | 34 | 33 |
| | Insufficient | 43 | 40 | 38 | 36 | 34 | 33 | 37 | 37 | 36 | 33 | 32 | 32 |
| | Recommended | 42 | 41 | 42 | 42 | 40 | 39 | 44 | 23 | 26 | 31 | 34 | 35 |
| EUR-C | Inactive | 18 | 19 | 23 | 32 | 37 | 39 | 21 | 28 | 28 | 39 | 40 | 41 |
| | Insufficient | 38 | 34 | 32 | 30 | 28 | 28 | 32 | 31 | 30 | 27 | 27 | 26 |
| | Recommended | 44 | 47 | 45 | 38 | 35 | 33 | 47 | 41 | 42 | 34 | 33 | 33 |
| SEAR-B | Inactive | 14 | 16 | 16 | 17 | 15 | 16 | 16 | 18 | 18 | 18 | 17 | 17 |
| | Insufficient | 43 | 43 | 43 | 47 | 52 | 52 | 41 | 41 | 41 | 45 | 50 | 50 |
| | Recommended | 43 | 41 | 41 | 36 | 33 | 32 | 43 | 41 | 41 | 37 | 33 | 33 |
| SEAR-D | Inactive | 14 | 18 | 18 | 21 | 23 | 21 | 18 | 20 | 20 | 23 | 25 | 28 |
| | Insufficient | 42 | 38 | 36 | 34 | 32 | 31 | 36 | 35 | 34 | 32 | 30 | 30 |
| | Recommended | 44 | 44 | 46 | 45 | 45 | 48 | 46 | 45 | 46 | 45 | 45 | 42 |
| WPR-A | Inactive | 15 | 16 | 17 | 19 | 18 | 18 | 17 | 19 | 19 | 20 | 18 | 18 |
| | Insufficient | 50 | 56 | 53 | 52 | 56 | 55 | 48 | 49 | 50 | 49 | 55 | 54 |
| | Recommended | 35 | 28 | 30 | 29 | 26 | 27 | 35 | 32 | 31 | 31 | 27 | 28 |
| WPR-B | Inactive | 14 | 17 | 16 | 19 | 20 | 21 | 16 | 17 | 18 | 21 | 22 | 21 |
| | Insufficient | 41 | 40 | 41 | 41 | 44 | 41 | 40 | 39 | 38 | 38 | 41 | 38 |
| | Recommended | 45 | 43 | 43 | 40 | 36 | 38 | 44 | 44 | 44 | 41 | 37 | 41 |

**Table 10.26** Projected estimates (%) of physical inactivity in year 2020

| | | *Males* | | | | | | *Females* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Subregion* | *Exposure level* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* |
| AFR-D | Inactive | 11 | 13 | 13 | 16 | 18 | 19 | 13 | 12 | 13 | 16 | 19 | 20 |
| | Insufficient | 48 | 48 | 48 | 46 | 44 | 43 | 45 | 52 | 51 | 48 | 46 | 45 |
| | Recommended | 41 | 39 | 39 | 38 | 38 | 38 | 42 | 36 | 36 | 36 | 35 | 35 |
| AFR-E | Inactive | 9 | 12 | 12 | 15 | 16 | 17 | 11 | 11 | 11 | 14 | 16 | 16 |
| | Insufficient | 50 | 51 | 50 | 49 | 47 | 46 | 47 | 56 | 55 | 51 | 50 | 50 |
| | Recommended | 41 | 37 | 38 | 36 | 37 | 37 | 42 | 33 | 34 | 35 | 34 | 34 |
| AMR-A | Inactive | 17 | 19 | 20 | 21 | 22 | 32 | 21 | 23 | 21 | 27 | 31 | 41 |
| | Insufficient | 44 | 47 | 44 | 40 | 40 | 35 | 36 | 41 | 40 | 38 | 36 | 31 |
| | Recommended | 39 | 34 | 36 | 39 | 38 | 33 | 43 | 36 | 39 | 35 | 33 | 28 |
| AMR-B | Inactive | 17 | 19 | 20 | 23 | 26 | 29 | 24 | 28 | 28 | 38 | 41 | 42 |
| | Insufficient | 42 | 44 | 41 | 39 | 36 | 35 | 33 | 32 | 31 | 30 | 30 | 29 |
| | Recommended | 41 | 37 | 39 | 38 | 38 | 36 | 43 | 40 | 41 | 32 | 29 | 29 |
| AMR-D | Inactive | 17 | 19 | 19 | 23 | 28 | 31 | 22 | 26 | 30 | 40 | 47 | 48 |
| | Insufficient | 38 | 38 | 33 | 32 | 30 | 29 | 28 | 26 | 24 | 24 | 22 | 22 |
| | Recommended | 45 | 43 | 48 | 45 | 42 | 40 | 50 | 48 | 46 | 36 | 31 | 30 |
| EMR-B | Inactive | 16 | 19 | 19 | 22 | 25 | 27 | 19 | 21 | 21 | 25 | 31 | 33 |
| | Insufficient | 41 | 39 | 38 | 36 | 32 | 32 | 36 | 36 | 35 | 32 | 31 | 30 |
| | Recommended | 43 | 42 | 43 | 42 | 43 | 41 | 45 | 43 | 44 | 43 | 38 | 37 |
| EMR-D | Inactive | 15 | 18 | 19 | 21 | 23 | 26 | 18 | 20 | 20 | 24 | 30 | 31 |
| | Insufficient | 42 | 38 | 36 | 35 | 32 | 31 | 36 | 36 | 35 | 32 | 31 | 30 |
| | Recommended | 43 | 44 | 45 | 44 | 45 | 43 | 46 | 44 | 45 | 44 | 39 | 39 |

*continued*

**Table 10.26** Projected estimates (%) of physical inactivity in year 2020 (*continued*)

| | | *Males* | | | | | | *Females* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Subregion* | *Exposure level* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* |
| EUR-A | Inactive | 14 | 15 | 16 | 19 | 20 | 22 | 17 | 19 | 19 | 23 | 25 | 28 |
| | Insufficient | 52 | 57 | 55 | 52 | 50 | 47 | 47 | 51 | 51 | 45 | 45 | 42 |
| | Recommended | 34 | 28 | 29 | 29 | 30 | 31 | 36 | 30 | 30 | 32 | 30 | 30 |
| EUR-B | Inactive | 15 | 19 | 20 | 22 | 26 | 28 | 19 | 21 | 21 | 27 | 32 | 33 |
| | Insufficient | 43 | 40 | 38 | 36 | 34 | 33 | 37 | 37 | 36 | 33 | 32 | 32 |
| | Recommended | 42 | 41 | 42 | 42 | 40 | 39 | 44 | 42 | 43 | 40 | 36 | 35 |
| EUR-C | Inactive | 18 | 19 | 23 | 32 | 38 | 39 | 14 | 17 | 17 | 17 | 16 | 16 |
| | Insufficient | 38 | 34 | 32 | 30 | 28 | 28 | 32 | 31 | 30 | 27 | 27 | 26 |
| | Recommended | 44 | 47 | 45 | 38 | 34 | 33 | 54 | 52 | 53 | 56 | 57 | 58 |
| SEAR-B | Inactive | 14 | 17 | 17 | 17 | 16 | 16 | 16 | 19 | 18 | 19 | 17 | 17 |
| | Insufficient | 43 | 43 | 43 | 47 | 52 | 52 | 41 | 41 | 41 | 45 | 50 | 50 |
| | Recommended | 43 | 40 | 40 | 36 | 32 | 32 | 43 | 40 | 41 | 36 | 33 | 33 |
| SEAR-D | Inactive | 14 | 18 | 19 | 21 | 23 | 22 | 18 | 20 | 20 | 23 | 25 | 28 |
| | Insufficient | 42 | 38 | 36 | 34 | 32 | 31 | 36 | 35 | 34 | 32 | 30 | 30 |
| | Recommended | 44 | 44 | 45 | 45 | 45 | 47 | 46 | 45 | 46 | 45 | 45 | 42 |
| WPR-A | Inactive | 15 | 16 | 17 | 18 | 17 | 17 | 17 | 19 | 19 | 20 | 18 | 18 |
| | Insufficient | 50 | 56 | 53 | 52 | 56 | 55 | 48 | 49 | 50 | 49 | 55 | 54 |
| | Recommended | 35 | 28 | 30 | 30 | 27 | 28 | 35 | 32 | 31 | 31 | 27 | 28 |
| WPR-B | Inactive | 15 | 17 | 16 | 19 | 20 | 22 | 16 | 18 | 18 | 22 | 22 | 21 |
| | Insufficient | 41 | 40 | 41 | 41 | 44 | 41 | 40 | 39 | 38 | 38 | 41 | 38 |
| | Recommended | 44 | 43 | 43 | 40 | 36 | 37 | 44 | 43 | 44 | 40 | 37 | 41 |

**Table 10.27** Projected estimates (%) of physical inactivity in year 2030

| | | *Males* | | | | | | *Females* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Subregion* | *Exposure level* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* |
| AFR-D | Inactive | 11 | 13 | 13 | 16 | 18 | 19 | 13 | 12 | 13 | 16 | 19 | 20 |
| | Insufficient | 48 | 48 | 48 | 46 | 44 | 43 | 45 | 52 | 51 | 48 | 46 | 45 |
| | Recommended | 41 | 39 | 39 | 38 | 38 | 38 | 42 | 36 | 36 | 36 | 35 | 35 |
| AFR-E | Inactive | 9 | 12 | 12 | 15 | 16 | 17 | 11 | 10 | 11 | 14 | 16 | 16 |
| | Insufficient | 50 | 51 | 50 | 49 | 47 | 46 | 47 | 56 | 55 | 51 | 50 | 50 |
| | Recommended | 41 | 37 | 38 | 36 | 37 | 37 | 42 | 34 | 34 | 35 | 34 | 34 |
| AMR-A | Inactive | 17 | 19 | 20 | 20 | 22 | 32 | 21 | 23 | 21 | 26 | 31 | 40 |
| | Insufficient | 44 | 47 | 44 | 40 | 40 | 35 | 36 | 41 | 40 | 38 | 36 | 31 |
| | Recommended | 39 | 34 | 36 | 40 | 38 | 33 | 43 | 36 | 39 | 36 | 33 | 29 |
| AMR-B | Inactive | 17 | 19 | 20 | 23 | 26 | 29 | 24 | 28 | 29 | 38 | 41 | 42 |
| | Insufficient | 42 | 44 | 41 | 39 | 36 | 35 | 33 | 32 | 31 | 30 | 30 | 29 |
| | Recommended | 41 | 37 | 39 | 38 | 38 | 36 | 43 | 40 | 40 | 32 | 29 | 29 |
| AMR-D | Inactive | 17 | 19 | 19 | 23 | 29 | 31 | 22 | 26 | 30 | 40 | 47 | 48 |
| | Insufficient | 38 | 38 | 33 | 32 | 30 | 29 | 28 | 26 | 24 | 24 | 22 | 22 |
| | Recommended | 45 | 43 | 48 | 45 | 41 | 40 | 50 | 48 | 46 | 36 | 31 | 30 |
| EMR-B | Inactive | 16 | 19 | 20 | 23 | 25 | 27 | 19 | 21 | 21 | 25 | 31 | 33 |
| | Insufficient | 41 | 39 | 38 | 36 | 32 | 32 | 36 | 36 | 35 | 32 | 31 | 30 |
| | Recommended | 43 | 42 | 42 | 41 | 43 | 41 | 45 | 43 | 44 | 43 | 38 | 37 |
| EMR-D | Inactive | 15 | 18 | 19 | 22 | 23 | 26 | 18 | 20 | 20 | 24 | 30 | 32 |
| | Insufficient | 42 | 38 | 36 | 35 | 32 | 31 | 36 | 36 | 35 | 32 | 31 | 30 |
| | Recommended | 43 | 44 | 45 | 43 | 45 | 43 | 46 | 44 | 45 | 44 | 39 | 38 |

*continued*

**Table 10.27** Projected estimates (%) of physical inactivity in year 2030 (*continued*)

| | | *Males* | | | | | | *Females* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Subregion* | *Exposure level* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* | *15–29* | *30–44* | *45–59* | *60–69* | *70–79* | *≥80* |
| EUR-A | Inactive | 14 | 15 | 16 | 19 | 20 | 22 | 17 | 18 | 19 | 23 | 24 | 28 |
| | Insufficient | 52 | 57 | 55 | 52 | 50 | 47 | 47 | 51 | 51 | 45 | 45 | 42 |
| | Recommended | 34 | 28 | 29 | 29 | 30 | 31 | 36 | 31 | 30 | 32 | 31 | 30 |
| EUR-B | Inactive | 15 | 19 | 20 | 22 | 26 | 29 | 19 | 21 | 22 | 27 | 32 | 33 |
| | Insufficient | 43 | 40 | 38 | 36 | 34 | 33 | 37 | 37 | 36 | 33 | 32 | 32 |
| | Recommended | 42 | 41 | 42 | 42 | 40 | 38 | 44 | 42 | 42 | 40 | 36 | 35 |
| EUR-C | Inactive | 18 | 19 | 23 | 32 | 38 | 39 | 21 | 28 | 28 | 40 | 40 | 41 |
| | Insufficient | 38 | 34 | 32 | 30 | 28 | 28 | 32 | 31 | 30 | 27 | 27 | 26 |
| | Recommended | 44 | 47 | 45 | 38 | 34 | 33 | 47 | 41 | 42 | 33 | 33 | 33 |
| SEAR-B | Inactive | 15 | 17 | 17 | 17 | 16 | 16 | 16 | 19 | 19 | 19 | 18 | 18 |
| | Insufficient | 43 | 43 | 43 | 47 | 52 | 52 | 41 | 41 | 41 | 45 | 50 | 50 |
| | Recommended | 42 | 40 | 40 | 36 | 32 | 32 | 43 | 40 | 40 | 36 | 32 | 32 |
| SEAR-D | Inactive | 14 | 18 | 19 | 22 | 23 | 22 | 18 | 20 | 20 | 23 | 26 | 28 |
| | Insufficient | 42 | 38 | 36 | 34 | 32 | 31 | 36 | 35 | 34 | 32 | 30 | 30 |
| | Recommended | 44 | 44 | 45 | 44 | 45 | 47 | 46 | 45 | 46 | 45 | 44 | 42 |
| WPR-A | Inactive | 15 | 15 | 16 | 18 | 17 | 17 | 16 | 19 | 18 | 20 | 17 | 18 |
| | Insufficient | 50 | 56 | 53 | 52 | 56 | 55 | 48 | 49 | 50 | 49 | 55 | 54 |
| | Recommended | 35 | 29 | 31 | 30 | 27 | 28 | 36 | 32 | 32 | 31 | 28 | 28 |
| WPR-B | Inactive | 15 | 17 | 16 | 19 | 20 | 22 | 16 | 18 | 18 | 22 | 22 | 21 |
| | Insufficient | 41 | 40 | 41 | 41 | 44 | 41 | 40 | 39 | 38 | 38 | 41 | 38 |
| | Recommended | 44 | 43 | 43 | 40 | 36 | 37 | 44 | 43 | 44 | 40 | 37 | 41 |

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## Note

1 See preface for an explanation of this term.

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