Physical activity in the community: correlates of change and overall mortality in two population-based cohorts

Cecilia Inés Cornelio

TESI DOCTORAL UPF / 2014

Director:
Dr. Esteve Fernández, MD, MPH, PhD
Institut Català d'Oncologia, Universitat de Barcelona

Co Director:
Dr. Fernando García-Benavides, MD, PhD
Center for Research in Occupational Health

Department of Experimental and Health Sciences, Universitat Pompeu Fabra

Dedicada a la memoria de mi madre, Inés

Por sus valores, por la motivación constante
aún en la ausencia,
que me ha permitido ser una persona de bien,
pero más que nada, por su amor

ACKNOWLEDGEMENTS

¡La tesis!... Y finalmente el día que ya pensaba que nunca llegaría, ha llegado.

Y estoy segura que no es solo el fruto del esfuerzo personal, de la constancia, de la motivación y la automotivación, es GRACIAS a esas personas que he encontrado en este quizá largo camino.

Y en ese camino,… *que se hace al andar*..., ha estado Esteve Fernández; por su enorme voluntad y paciencia, por su confianza, por su generosidad, por su ciencia y conciencia, por su saber, por la epidemiología que enseña y ejerce, esta Tesis ha sido posible. Para agradecerte tengo principalmente la confianza depositada en mi como individuo y como profesional, nosotros sabemos -ambos- que esto ha sido muy importante en el desarrollo del proyecto, un proyecto difícil desde el origen, por la obtención de la beca, por la que insistí durante dos años, por la distancia, por las cuestiones personales y familiares que tuve que transitar coincidentemente con este propósito. No cabe en este espacio de papel todo el agradecimiento y aprecio que te debo. Gracias por siempre y para siempre.

Y quién me recomendara, también depositando en mí su mayor confianza, casi conociéndome poco, mi compatriota Carlos Alberto González, que con mucha intuición me dirigió a contactar a Esteve en el ICO, gracias Carlos, has sido un eslabón insoslayable en este recorrido.

Para completar el camino, encontramos intereses comunes en la última etapa de la trayectoria de este doctorado con el Profesor Fernando García Benavides; gracias a su experiencia, a su motivación y al impulso que le ha dado a este proyecto hoy puedo completar esta aspiración y esta meta de obtener el doctorado por la Universitat Pompeu Fabra. Y seguramente esta etapa abrirá otras de interés mutuo por la epidemiología ocupacional y de los estilos de vida, áreas de mi pretensión e interés de estudio.

Ha sido un placer de estos últimos tiempos conocer a los colegas del CISAL, tan aplicados y generosos con sus conocimientos,

también a la secretaría de Fernando, a Montserrat, a Natalia, a los compañeros Javier, Pamela, Sergio, Emily, a Elena Ronda. Qué gusto me ha dado compartir conferencias, charlas y proyectos. Han sido todos muy amables, cálidos y gentiles.

Gracias a la Dra. Carme Borrell por su gentileza en ceder la base de datos de la Encuesta de Salud de Barcelona, por la confianza depositada y la revisión de los manuscritos.

Un párrafo aparte merecen los colegas y compañeros del ICO, de la Unidad de Prevención y Control del Cáncer, desde el primer día de mi llegada a BCN y al ICO he sentido la calidez de compañeros de trabajo, me han brindado sus conocimientos en investigación epidemiológica, su confianza, su ayuda -con la informática, el printer, la biblioteca virtual, el desayuno, las comidas, los viajes, la compañía, la solidaridad, etc.-, en fin… brindándome todos los recursos que tenían a disposición, y tal vez lo más rico de lo cotidiano: su tiempo y su amistad. ¡A Montse García no alcanzan las palabras para expresarle mi reconocimiento, hemos trabajado con las fichas de la cohorte de Cornellà hasta la noche durante la primera etapa del doctorado!, con mi primer paper ha estado presente resolviendo mis dudas, ansiedades y mis inquietudes: gracias Montse por tu generosidad, sos alguien muy especial, muy sabia y me hubiera gustado poder compartir muchos más saberes contigo y Esteve, para seguir aprendiendo. A Anna, Marcela, Olga, Naty, Mercè Margalef, Carmen, Cristina, Gemma y todos -no quisiera dejar de mencionar a nadie- muchas gracias, nunca me sentí extranjera en el ICO.

Y como si todo esto fuera poco, he encontrado una familia que me brindó no solo su casa sino su hogar, para estudiar y sentirme como en la mía, desinteresadamente, tan compañeros, tan cálidos y solidarios, gracias Kika (Enriqueta) y Carlos Martín, por hospedarme, por la hospitalidad, por cuidarme, por ayudarme y también por hacerme sentir cómoda estando lejos de mi país y mi familia.

Pero además de la gente de Barcelona que he mencionado, este proyecto -esta aventura- en el extranjero no hubiera sido posible si no hubiera contado con el apoyo de mis entrañables amigos en Argentina: Claudia Fasani y Oscar Levalle, han estado a mi

lado incondicionalmente cuidando lo más preciado que tenemos, nuestros hijos, mi casa y mi corazón; y con el sostén de la Dra. Mariela Rossi.

Del mismo modo mi familia, mis primos Gabriela y Ricardo Basílico, que han compartido y estimulado mis estudios, progresos y viajes, que han estado siempre para lo que necesitemos; sé que estarán orgullosos de que pueda llegar a esta meta que también debo a ustedes.

Y a mis compañeras de la London School, con las cuales nos une una Amistad (¡con mayúsculas!) y la pasión por la epidemiología y la salud pública y los projects, aquí en BCN, en Rosario -Argentina-, en UK, en muchas partes del mundo, gracias Nuria Lara por tu apoyo y sostén cuando extrañaba a mis hijos, gracias Adriana Silvestre por tus sabios consejos, por tu calidez, por tu onda, por la motivación para seguir cuando casi me dejo caer.

Y a mis amigas de Argentina, Adriana, Graciela, Lili, que ayudaron, apoyaron y escucharon cada una de mis quejas, mis ideas, y mis llantos y son testigos de este esfuerzo y de la alegría y satisfacción del trabajo realizado.

A mis compañeros de la SRT, Mary y Alfredo con los cuales compartimos días de trabajo, proyectos, charlas, compañía, buenos y malos ratos pero siempre colaborando con el valor agregado de la amistad. También a María Hebe por el diseño y la predisposición incondicional, y a María José por el apoyo.

Y sin lugar a dudas, así como en lo académico y en la epidemiología ha estado Esteve, en todo lo demás debo esta Tesis a mis hijos, a mis tesoros, a Sofía y Gustavo, que han sacrificado días de “mamá” por mis viajes, que han compartido el estrés de los papers, de los análisis de STATA, con todo lo que significa separase físicamente de su madre; les debo el apoyo, el “aguante”, han comprendido que la meta era esta y que había que seguir, con sus dificultades y sus placeres; confío hijos que este ejemplo de trabajo y voluntad nutra sus valores.

Y en esta última etapa, a Juan que con su amor pudo comprender que este último esfuerzo había que hacerlo: hay que hacerlo Ceci, ¡vamos!, gracias por estar a mi lado y permitirme con libertad poder alcanzar la meta, el lugar soñado y el título anhelado, es un broche de oro tu compañía.

Los caminos de la vida tal vez nos junten, nos separen o nos reencuentren, por eso es importante escribir este capítulo, para dejar por siempre y para siempre mi agradecimiento. Muchas gracias a todos.

Moltes gràcies a tots.

Summary

Physical inactivity is a major public health problem, and evidence suggests that it is a contributing factor in numerous chronic diseases and conditions. Along with smoking and poor dietary habits, physical inactivity is one of the main risk factors for chronic diseases that can be modified through behavior change Performing physical activity on a regular basis has been linked with positive effects on health and well-being, and physical activity improvement has been appointed as the leading health indicator for the next decades. The availability of health data is important for national discussions on health policies. Such data can highlight real variations in health status and the factors affecting health across communities. Moreover, it could be useful to guide policy-related discussions on best practices to improve the health of population.

The objectives of this thesis are to describe changes on leisure time and occupational physical activity status at the community level and to evaluate sociodemographic, health related, and life style determinants of such changes, and also, to evaluate the association of different physical activity domains for women and men, with overall mortality.

The thesis is composed by two original articles based on two population-based cohorts studies: the Cornellà Health Interview Survey Follow-Up Study and the Barcelona Health Interview Study.

The studies included in this thesis suggest that there were changes in the physical activity status of the population, whereas no clear determinants of such changes were recognized. Moreover the effects of all domains of physical activity were associated with a substantial decreased mortality. Therefore, promoting moderate levels of leisure time physical activity, occupational physical activity and walking seem to be essential in comprehensive health promotion programs at community levels.

Resumen

La inactividad física o el sedentarismo es un problema central de la salud pública, la evidencia científica muestra que es un factor de riesgo para numerosas enfermedades de las denominadas crónicas o no transmisibles. Junto al hábito de fumar y a la alimentación es un factor de riesgo de enfermedad que puede ser modificado por cambios de comportamiento y hábitos. Se postula que realizar actividad física de manera regular permite lograr efectos positivos sobre el bienestar y la salud; además, el mejoramiento en los niveles de actividad ha sido señalado como un indicador líder de las ganancias en salud. En este sentido disponer de datos poblacionales es fundamental para discutir las políticas públicas sanitarias: las variaciones a nivel poblacional de los indicadores de salud son los que guían las discusiones para desarrollar guías que mejoren la salud comunitaria.

Los objetivos de la presente tesis son: describir los cambios en la actividad física de ocio y la ocupacional a nivel comunitario y evaluar los determinantes de dichos cambios tales como los sociodemográficos, los relacionados con el status de salud, y los estilos de vida; Identificar la asociación de los distintos dominios de actividad física con la mortalidad general tanto en hombres como en mujeres en estudios de cohortes de base poblacional.

La tesis se compone de artículos originales desarrollados en el marco de dos estudios de cohortes con base poblacional, el Estudio de Seguimiento de la Cohorte de Cornellà y el de La Encuesta de Salud de Barcelona año 2000.

Los estudios analizados evidencian que hubo cambios en los niveles de actividad física a nivel poblacional, y que no se demostraron determinantes claros de esos cambios más que los sociodemográficos. También demostraron que todos los dominios de actividad física realizada tanto en mujeres como en hombres decrecen la mortalidad por todas las causas evaluada a nivel poblacional. Por lo tanto para el diseño de programas abarcativos de promoción de la salud a nivel comunitario deben incluirse recomendaciones apropiadas para la realización de actividad física de ocio y del caminar y laboral.

Preface

This thesis was completed at the Cancer Prevention and Control Unit of the Institut Català d'Oncologia, under the supervision of Dr. Esteve Fernández with the co-direction of Prof. Fernando Garcia Benavides from the Universitat Pompeu Fabra. It was presented as a collection of publications according to the PhD in Biomedicine program regulations at the Department of Experimental and Health Sciences at the University Pompeu Fabra.

This thesis was made possible with the collaboration of different researchers in Barcelona. The first study was done into the frame of the Cornellà Health Interview and their follow-up study, directed by Dr. Esteve Fernández and colleagues of the Catalan Institute of Oncology, Prevention Cancer Unity. The second one was performed using the dataset collected by the Public Health Agency of Barcelona, the Barcelona Health Survey and the study linkage with de Mortality Registry of that city, under de direction of Dr. Carme Borrell and her team at the Public Health Agency.

My personal contributions in the production of the articles presented in this thesis include, a literature review, study design, statistical analysis of the data and interpretation of results, and writing of the reports.

The thesis is formed by the following two papers:

Paper 1
Cornelio CI, García M, Schiaffino A, Borrès JM, Nieto FJ, Fernández E. Changes in leisure time and occupational physical activity over 8 years: the Cornellà Health Interview Survey Follow-Up Study. *J Epidemiol Community Health*. 2008; **62**(3):239–44.

Paper 2
Cornelio CI, Fernández, Marí-Dell'Olmo M, Borrell C. Physical activity and mortality in a prospective cohort of women and men in a Mediterranean population. Submitted

Index

Abbreviation List

PA	Physical Activity
LTPA	Leisure Time Physical Activity
OPA	Occupational Physical Activity
ICO	Institut Català d´Oncología
CHIS	The Cornella Health Interview Survey
CHIS.FU	Cornella Health Survey Interview Follow-Up

PART 1

Introduction

INTRODUCTION

1.1 Overview

Performing physical activity on a regular basis has been linked with positive effects on health and well-being.[1, 2] Its association with reduction of all-cause mortality is also established.[3-7] In addition, physical activity has many other health benefits, including reduced risk of cardiovascular diseases, stroke, depression, and diabetes[7-10]. The evidence for a beneficial effect of physical activity on cancer is growing, mainly for some of the major cancer sites: colon, breast and prostate.[11, 12]

All of these cumulated evidence relating to the health benefits of increasing PA has resulted in guidelines that emphasizes the utility of the "physical exercise" approach[1, 13, 14, 15], and promoting heart-healthy behaviours is a major strategy to reduce the development of cardiovascular disease, among other chronic disorders.[15] Despite increasing awareness and commitment concerning these issues, the United Nations have voiced their ongoing concern about the increase in non-communicable diseases which are now responsible for more deaths than all other causes combined, pointing out that physical activity is one of the few proven and affordable measures to prevent this fatal outcome.[16, 17]

Although most of the recommendations hinge on individuals' behaviour and focus primarily on activities based on clinical settings, the importance of population-level determinants is also recognized[18]. Therefore, the role of community-based intervention to promote healthy changes in physical activity is of importance in a global strategy for health promotion and prevention.

Therefore, understanding the balance made by increasing sedentarism trends and activity patterns in each community is fundamental to prevent adverse health consequences or delayed onset of non-communicable diseases from a contemporary perspective.[19, 20]

1.2 Leisure time (LTPA) and occupational (OPA) physical activity status in the community

The availability of health data is important for national discussions on health policies. Such data can highlight real variations in health status and the factors affecting health across communities, and can then guide policy-related discussions on best practices to improve the health of populations. As the importance of health information systems for decision-making has increased, health interview surveys remain a unique source of data for some essential indicators. In health surveys, quantifying physical activity (PA) has been used as an approach to a major behavioral determinant of health.

Information of the level of PA –Leisure Time Physical Activity (LTPA) and Occupational Physical activity (OPA)- in Barcelona, Spain was collected in some health surveys as the Health Interview Survey of Barcelona in 1992.[21, 22] From that assessment the conclusion was that 20% of population was inactive, 60.7% of population participated in light activities or less than three times in moderate and/or intense LTPA (moderately active people), and only 19.3% performed exercise moderate and/or intense exercise on a more regular basis (3 times/week or more) (vigorously active people). Inactivity was higher in women than in men (22% vs. 17.5%). A major difference between men and women was observed in the 15-24 years old group, whilst there were minor differences in the 45-65 years old group. In the analysis of the information, if recoding as inactive those people who performed less than three times moderate and/or intense LTPA, the survey found that inactivity increase with age, and in people with a low socioeconomic level. Men and women with incomplete primary studies were more likely to be inactive than people with graduate studies. Smoker men were more inactive than non-smokers. Regarding OPA, 50% of the population surveyed reported being physically active, but activity was lower among workers than non-workers, although workers reported more physical effort. OPA was associated with occupation and educational level among male workers, but only with occupation among female workers. Non-workers with a poor self-perceived health status did less physical activity. Data from The Catalonian Health Interview Survey carried out in 2006 shows that

sedentarism increased moderately from 1994 to 2006, reaching to 25.8% of the population.[23]

In spite of the high level of inactivity detected by the Barcelona Health Interview Survey, the Spanish National Health Surveys carried out in 1987, 1995 and 1997 showed a positive attitude of the population towards performing any variety of LTPA.[24-26] During that period both men and women of all age groups had increased their activity. In the period 1987-1995/1997 the prevalence of intense or regular LTPA increased by 5.7 and 6.2 % in women and men, respectively.[27] However, regardless of those improvements, inequalities between gender and social class were evident and increasing from 1987 to 1993.[28, 29] Inactivity increases as socioeconomic status decreases. Moreover, the percentage of inactivity is high in the Spanish regions with low income per capita. In the last decade, the National Health Survey carried out during the year 2011 and 2012 showed that at least one out of six adults has any of the chronic disease risk factors such as: low back pain (18.6%), high blood pressure (18.5%), and high serum cholesterol levels (16.4%). Trends of chronic conditions and risk factors of cardiovascular diseases seem continuously growing: from 1993 hypertension has increased from 11.2% to 18.5%, diabetes from 4.1% to 7.0% and high cholesterol from 8.2% to 16.4%. Obesity affects 17.0% of the population. From the First National Health Survey in 1987, obesity has increased in both men and women, more notorious among male than in women; while in 1987 7.4% has a BMI equal or more than 30 kg/m2, in 2012 that percentage reaches 17%. 54% of the population has overweight or obesity. Regarding PA, four out of ten interviewed peoples declared to be sedentary (35.9% and 46.6% male and women respectively). Considering occupational, commuting and leisure time, 40% reported at moderate-intense PA, near 50% in male and 30% in women.[30] A more recent paper analyzed time- trends in Physical activity in Spanish populations, and found an increase in leisure time physical activity in the older population.[31]

1.3 Measuring physical activity

Many studies of physical activity have been done. These studies include cross-sectional investigations, randomised controlled trials,

and cohort studies.[3-12] The highest quality research study in humans is the randomised controlled trial (RCT), and short term RCTs have looked at the effect of exercise on risk factors. A longer RCT of physical activity with more definite outcomes would be ideal but difficult. Cross-sectional studies compare activity levels and risk factors in various population groups although their ability to establish causal relationship is null. Cohort studies follow groups of people over time, measuring the outcome of different exposure to an agent, in this case: exercise. In practical terms, a cohort study is the observational design that allows identifying risk and protective factors.

Results from most studies are contradictory, and it has been suggested that part of the problem in identifying a relationship between PA and diseases has been the difficulty in assessing PA, with involving variation in measurement accuracy, that may be a source of heterogeneity contributing to inconsistent results among studies.[32]

Although there are several certain techniques for assessing PA, the cost and time burden required,[33] make them not suitable for epidemiological research. Hence, PA questionnaires are the most practical and widely used approach in epidemiologic research. Public health initiatives aimed at increasing physical activity depend on the measurement of physical activity to monitor their success. Physical activity is multidimensional, and a complex behaviour to measure; its various domains are often misinterpreted. Erroneous or crude measures of PA have serious implications, and are likely to lead to misleading results and underestimate effect size. Key definitions and theoretical aspects, which support the measurement of physical activity, are essential in evaluated the relayed information from papers.

While, the best way to measure PA is to observe people and record every activity, this is very difficult to implement with a large number of people. PA questionnaires vary from a few basic questions to a detailed recall diary looking back over weeks, months, or years. But measuring physical activity by questionnaire can be inaccurate, and even a subtle difference in the wording of a question can change the interpretation. The more detailed the diary or questionnaire, the better

as it is more likely to represent true activity. Although questionnaires have shortcomings, they are often the best available method.

Four main dimensions can be considered for PA measurement and vary extensively across studies, i.e. (1) type, (2) frequency, (3) duration, and (4) intensity of activity. According to use of divergent concepts of physical activity the focus of questions varies considerably between studies and countries even when related to the same dimension (i.e. Spanish Health Interview Study investigate the frequency of physical activity related to different forms of intensity (light, moderate, vigorous). And, in most cases different reference periods are used to report the frequency of physical activity (e.g. last 7 days, usual week, last 14 days, last 12 months).

Several criteria are used to assess the utility of questionnaires before using for research:

1) *Validity*: implies that a comparison is made with a superior, although typically imperfect, standard. A validation study can and should evaluate the questionnaire's assessment of the type of activity. Examples of different activity types include PA such as exercise, occupational activity, domestic activity, as well as childcare. A validation study should also assess the questionnaire's assessment of frequency –how often the activity is performed, its duration – how long it is performed for each bout, as well as its intensity– the effort expended to conduct the activity-. Unstructured activities (e.g., household activities) are often difficult for subjects to report accurately, and recreational activities may be more memorable since they may require planning or an effort that other activities do not. Different validation procedures are doing accordingly research objectives and across groups' populations, e.g. adults, adolescents, older adults, child, obese or pregnant women.[34, 35]

2) *Reliability*: implies the consistency of the measurements on more than one administration, to the same people at different times.

Comparison measures include both a) subjective measures (based on self-report of subjects), and b) objective measures (based on direct measurement): *Self-reported measures* can be self-

administered or interviewer administered, both in person or on the telephone; *Objective measures* include markers of movement (accelerometers), physiological responses that are affected by physical activity (i.e. heart-rate, sweat), direct measures of energy expenditure (doubly labelled water), and observed or video-taped activity (direct observation).

Other two important criteria to consider before deciding use a questionnaire are:

3) *Practicality*, the instrument should be practical in terms of both time and cost to the investigator and in terms of time for the participants.

4) *Relationship to disease*: The questionnaire results should been assessed in relationship to chronic disease or factors associated.

For further classifying sports and other recreational activities according to intensity and duration a Compendium of Physical Activity was developed to facilitate the coding of PA obtained from records, logs, and surveys.[36] It enhances the comparability of results across observational studies. It is defining metabolic equivalents (METs). One MET is defined as the energy expended per minute while sitting quietly for an hour and is equivalent to 3.5 ml of oxygen uptake per kilogram of body weight per minute for an adult weighing 70 kg. Summary estimates of energy expenditure must be calculated for the questionnaire. The number of times an activity is performed is multiplied by the number of hours spent on the activity at each session as well as its intensity defined in METs to arrive at a measure of total energy expenditure attributable to the activity.

An update of the initial compendium (developed in 1989 and published in 1993) has been published.[37] This update reflects public health interests in evaluating the contribution of various types of PA to daily energy expenditure by providing additional categories done during the day. The Compendium was used globally to quantify the energy cost of PA in adults for surveillance activities, research studies, and, in clinical settings, to write PA recommendations and to assess energy expenditure in individuals. Recently,[38] in 2011, the Compendium was updated as a system for quantifying the energy

cost of adult human PA. Approximately half (317/604) of the codes from the 2000 Compendium were modified to improve the definitions and/or to consolidate specific activities and to update estimated MET values where measured values did not exist. It is a living document that is moving in the direction of being 100% evidence based.

For the immediate future, the questionnaire methods of assessing PA will most likely remain the method of choice for epidemiologic research. However, questionnaires continue to be developed and improved to provide more accurate PA information to allow testing of specific hypotheses regarding the relationship between PA and several chronic diseases. New technologies as the use of mobile technologies for PA assessment, sedentary behavior assessment, and/or interventions for PA behavior change were included for analysis in a recent review,[39] concluding that new adaptive, sequential research designs that take advantage of ongoing technology development are needed.

1.4 Behavior change, health promotion and prevention

Physical inactivity is a major public health problem, and evidence suggests that it is a contributing factor in numerous chronic diseases and conditions.[17, 18] Along with smoking and poor dietary habits, physical inactivity is one of the main risk factors for chronic diseases that can be modified through behavior change.[18] Recognition of the health and functional hazards of a sedentary way of life has led numerous groups to developed public health recommendations for physical activity. Public recommendations and health promotion campaigns have been established for these major risk factors,[13-15, 40, 41] and also policy for physical activity being an integral part of chronic disease prevention and health promotion; and moreover, physical activity improvement had been appointed as the leading health indicator for the year 2010.[42]

A summary of current recommendations are listed below:

Adults:

- All adults should avoid inactivity. Some physical activity is better than none, and adults who participate in any amount of physical activity gain some health benefits.
- For substantial health benefits, adults should do at least 150 minutes (2 hours and 30 minutes) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Aerobic activity should be performed in episodes of at least 10 minutes, and preferably, it should be spread throughout the week.
- For additional and more extensive health benefits, adults should increase their aerobic physical activity to 300 minutes (5 hours) a week of moderate-intensity, or 150 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity activity. Additional health benefits are gained by engaging in physical activity beyond this amount.
- Adults should also do muscle-strengthening activities that are moderate or high intensity and involve all major muscle groups on 2 or more days a week, as these activities provide additional health benefits.

Although US national recommendations include advice on vigorous physical activity, the committee recommends focusing the message only on increasing physical activity in general. To reduce risk of injury, it is important to increase the amount of physical activity gradually over a period of weeks to months. For example, an inactive person could start with a walking program consisting of 5 minutes of slow walking several times each day, 5 to 6 days a week. The length of time could then gradually be increased to 10 minutes per session, 3 times a day, and the walking speed could be increased slowly.[2]

Young persons:

Children and adolescents should do 60 minutes (1 hour) or more of physical activity daily.[43]

- Aerobic: Most of the 60 or more minutes a day should be either moderate or vigorous-intensity aerobic physical activity, and should include vigorous-intensity physical activity at least 3 days a week.

- Muscle-strengthening: As part of their 60 or more minutes of daily physical activity, children and adolescents should include muscle-strengthening physical activity on at least 3 days of the week.
- Bone-strengthening: As part of their 60 or more minutes of daily physical activity, children and adolescents should include bone-strengthening physical activity on at least 3 days of the week.
- It is important to encourage young people to participate in physical activities that are appropriate for their age, that are enjoyable, and that offer variety.

We have reached a point where the health benefits of PA are well documented, there is some understanding of individual and environmental determinants of PA, appropriate data on intervention efficacy exists, recommendations for both individual PA and community interventions are clear, public health tools for surveillance and evaluation are in place, and a policy agenda provides a frame under which these components can work. However, as scientists and as a public health community we have not dedicated sufficient resources to adapt these approaches to diverse settings and populations and across several sectors, and suffice understanding of the balance sedentarism-activity in each community.[44]

While most of the guidelines have been done for individuals and offered into health care appointments, is also documented some modest effect at a population setting based in individual level recommendations to modify life styles or risk factors.[18, 45]

Changes in physical activity behavior have been used to assess effectiveness of such strategies of health promotion[46], and to relate physical activity behaviors with other factors implicated, i.e. smoking, obesity, diet and other socio demographic.[47, 48, 49]

Prospective studies in representative samples of the population may be helpful to assess the community status of physical activity change and to evaluate variables linked to changes in PA that can contribute towards designing better public health interventions to drive population level changes in the prevalence of PA.[48]

1.5 Morbidity and mortality in relation of physical activity

There is a huge body of evidence and agreement, both from a preventive and a rehabilitative viewpoint, that regular physical activity results in positive health-related outcomes, including reduction of all-cause-mortality.[50-52] An association of leisure time physical activity with overall mortality, with active persons having a longer life expectancy has been shown in different studies -mostly in Anglo-Saxon contexts.[53, 54] However it is not clear whether other domains of physical activity, such as occupational and daily commuting or walking are associated with lower risk of disease and death. Most of the studies on PA and mortality to date have been conducted among selected population groups [54, 55] and, moreover, there is scant evidence about those effects among women.[56, 57] Hence, prospective studies in representative samples of the general population can help to estimate the relative risk of death associated to different dimensions and levels of physical activity.[58] In addition, a joint effect between a healthy lifestyle and the process of healthy living are likely to occur; therefore, major determinants must be studied simultaneously. Cigarette smoking, higher body mass index, less physical activity, and a lower healthy diet score were all associated with increased cardiovascular, cancer, and all-cause mortality.[59, 60]

In a recent study of middle aged women, adherence to lifestyle guidelines involving a healthy diet, regular physical activity, and weight management was also associated with noticeably lower mortality and the results indicate that a healthy diet and regular physical activity have important health benefits independent of reducing adiposity.[61]

One recent systematic review and meta-analysis of prospective epidemiological studies in general population samples, to quantify relationships between all-cause mortality and different domains of PA, supports an inverse relationship between increasing levels of total and domain-specific physical activity and all-cause mortality, with stronger associations for women than for men, and for exercise and sports, leisure-time activities and activities of daily living than for occupational and transport-related activity.[62]

As PA is undertaken in different contexts or domains, which are related to occupation, the routines of daily living (e.g. domestic activities, active commuting) and leisure (e.g. recreational activities, exercise and sports); the intensity, duration and frequency within each of these domains are used to estimate the total amount of physical activity. Different culture and behaviors are well known exist across communities, therefore reductions in mortality per increment of time of physical activity whether due to vigorous exercise or moderate to vigorous leisure activities or for moderate activities of daily living, as well as physical activity for transportation and walking are expected to be investigated similarly for Mediterranean populations.

PART 2

Hypotheses and Objectives

2. Hypotheses and Objectives

2.1 Hypotheses

1. Changes in the status of physical activity measured at community level in the last two decades have occurred.
2. Such changes are related to socio-demographic characteristics, or community or individual interventions.
3. There is an association between physical activity domains and reductions of all-cause mortality at the community level.

2.2 Objectives

a) General Objective

To analyze the correlates of the changes on physical activity status and the association of physical activity domains with overall mortality at the community level.

b) Specific Objectives

- To describe changes on leisure time and occupational physical activity status at the community level.
- To evaluate sociodemographic, health related, and life style determinants of such changes.
- To estimate the association of different physical activity domains for women and men, with overall mortality in population-based cohorts in Mediterranean setting.

PART 3

Methods

3. Methods

Paper 1: Changes in leisure time and occupational physical activity over 8 years: the Cornellà Health Interview Survey Follow-Up Study

Summary of methods: we have used data from the Cornellà Health Interview Survey Follow-Up Study, a prospective cohort study of a representative sample of the population. We considered for this analysis 1246 subjects, 567 men and 679 women, who had complete data on physical activity at baseline in 1994 and at follow-up in 2002. We fitted Breslow-Cox regression models to assess the association between correlates of interest and changes in physical activity.

The Cornellà Health Interview Survey Follow-Up Study

This cohort was formed based on a previously cross-sectional survey of 2,500 people conducted in1994 (The Cornella Health Interview Survey). The specific aims of the Cornella Health Survey Interview Follow-Up (CHIS.FU) were: a) to analyze changes in smoking habit, alcohol consumption, and level of physical activity between 1994 (baseline interview) and 2002 (follow-up interview), and their sociodemographic determinants; b) to determine the mortality and incidence of cardiovascular diseases and cancer in the cohort and to analyze their association with socioeconomic status, self-perceived health, life styles, and chronic conditions. Secondary to this objective, the CHIS.FU provided new cross-sectional information to be used in further follow-up, otherwise we could use that data for the following analyses: c) to describe risk perception beliefs on cancer; d) to study the prevalence of exposure to second hand smoke and its determinants; e) to analyze social support variables and their association with self-perceived health, life-styles, and use of health care services; and, f) to analyze health locus of control in relation to lifestyles and mortality. Inception cohort: The baseline health and sociodemographic characteristics of subjects in this investigation were obtained from a cross-sectional survey, the Cornella Health Interview Survey (CHIS) carried out in 1994. Cornella de Llobregat (http://www.aj-cornella.es) is a town of approximately 85,000 inhabitants, mainly of working- and middle classes, located on the metropolitan area of Barcelona, Catalonia (Spain). A representative sample of the non-

institutionalized population (all ages) of 2,500 people (1,263 women and 1,237 men) was selected by simple random sampling from the Census and interviewed face-to-face during 1994 (12 months) to avoid seasonal variations.

The variables studied in the CHIS included sociodemographic and personal information (place of birth, age, sex, educational level and social class); height and weight, health behaviours (smoking habit, alcohol consumption, and physical activity); chronic conditions; self-perceived health; and use of health care services. Detailed information of the survey is available elsewhere.[63, 64, 65] Follow-up: 1994 with follow-up until death, migration or censoring date (30/07/02). Record linkage: In April 2000, we implemented a computerized record linkage to update the address and vital status of all 2,500 participants, with the objective of optimizing the response rate and improving direct tracing of cohort members. Afterwards, we attempted to trace the cohort members to conduct the phone follow-up interviews. Data in the CHIS.FU were managed centrally at the Prevention and Cancer Control Unit from the Catalan Institute of Oncology, following the confidentiality rules for this type of data.

The effort spent in locating cohort members improves the precision as well as the validity of the study results. In this study we obtained a full response from 64.2% of cohort members. In our study, the cohort population is defined by geographic boundaries so the follow-up was made among those subjects who were alive and who were still living in Cornella. Therefore, given that migrations and deaths are natural losses to follow-up, the actual participation rate after follow-up was 83.3% (1,605 interviews over 1,928 non-migrated and non-deceased cohort members). Although 94 cohort members refused to answer the general questionnaire, they provided basic information through the short questionnaire (total participation rate of 88.1%). *Study variables to PA analysis: Leisure time physical activity (LTPA)* and occupational physical activity (OPA) in the previous 7 days was assessed using adapted questionnaires from the US Health Interview Survey and in the Welsh Heart Health Study; these instruments have been previously used in similar population surveys.[21–22] LTPA was assessed with the following questions: During last week, how many times did you perform any light physical activity for at least 20

minutes (walking, light recreational activities, going upstairs)?; During last week, how many times did you perform any moderate physical activity for at least 20 minutes (riding a bike, gym, running, tennis, swimming)?; During last week, how many times did you perform any intense physical activity for at least 20 minutes (team sports, hockey, football, physical training)?; We then classified LTPA in 1994 and in 2002 into the following categories: sedentary: people who did not perform any activity; light/moderate: any number of times/week of light activity gathered from question 1 and up to two times/week of moderate or vigorous physical activity gathered from questions 2 and 3; and vigorous: more than two times/week any moderate or vigorous physical activity gathered from questions 2 and 3.OPA was assessed with the question: ‘‘Which of the following options best describes your main or usual activity?; Inactive: sitting down most of the day; Light: standing most of the day, with little movement or exertions of energy; Moderate: walking, carrying some weight, frequent movement; Intense: physical effort and heavy labour. We then classified OPA in 1994 and in 2002 into two main categories: sedentary: subjects who answered options 1 or 2 and; and active: subjects who replied options 3 and 4 as daily activities. To further characterise subjects’ profile regarding LTPA and OPA changes at follow-up, we defined a ‘‘positive’’ change when an upper level of physical activity was reached in 2002 from a ‘‘sedentary’’ status in 1994. A ‘‘negative’’ LTPA change was identified when subjects changed from ‘‘light/moderate’’ to ‘‘sedentary’’ LTPA. A ‘‘negative’’ OPA change was identified when subjects changed from ‘‘active’’ OPA in 1994 to ‘‘sedentary’’ in 2002.

Other independent variables in these analyses included sociodemographic characteristics as measured in 1994: sex, age (15–24 years; 25–44 years; 45–64 years; >65 years), maximum educational level attained (less than primary or primary studies; secondary or university studies) and social class categorised in terms of occupation. Social class was defined following the Spanish adaptation of the British Registrar General classification 18: class I (directives of the public administration and managers of companies with 10 or more employees, professionals associated with advanced university degree); class II (managers of companies with fewer than 10 employees, professionals associated with initial university degree,

technicians and support professionals, artists, sportsmen); class IIIa (administrative workers and support professionals in administrative and financial management, workers in personal and security services); class IIIb (self-employed workers); class IIIc (supervisors of manual workers); class IVa (high skilled manual workers); class IVb (semiskilled manual workers); and class V (unskilled manual workers). For the analysis, we grouped these categories in three levels: class I-II, class III (IIIa + IIIb), and class IV-V (IVa + IVb + V). We also used working status according to main activity (employed; unemployed; disabled or retired; student; housewife).

Lifestyle variables: smoking (never smokers; former smoker; current smokers; including occasional and daily smokers), alcohol consumption (non-drinkers and thirds of consumption in g/day according to the separate distribution in men and women) and health-related variables: number of chronics conditions (0; 1 and >2); self-perceived health (recoded into two categories as ‘‘suboptimal’’ if subjects declared themselves to have a ‘‘poor rather bad,’’ ‘‘bad,’’ or ‘‘very bad’’ health and as ‘‘optimal’’ if they declared themselves to have a ‘‘poor rather good,’’ ‘‘good,’’ or ‘‘very good’’ health) and body mass index (BMI) calculated as weight/height squared (kg/m2). ‘‘Obesity/overweight’’ was defined as BMI >25.0 kg/m2; BMI between 18.5 and 24.9 kg/m2 was considered ‘‘normal’’ weight.

In order to investigate the variables that were associated with changes in physical activity, we fitted Breslow-Cox regression models to calculate the hazard ratio (HR) of change in LTPA and OPA and corresponding 95% confidence intervals (CI).The assumption of proportionality of hazards was verified using standard graphic and statistical methods. Separate analyses for men and women were conducted. All models were adjusted for age and, when necessary, for other potential confounders.

Paper 2: Physical activity and mortality in a prospective cohort of women and men in a Mediterranean population.

Summary of methods: we use data from the 2000 Barcelona Health Interview Survey Follow-Up Study. The survey collected socio-

demographic data and information about chronic conditions, life styles (including physical activity), self-perceived health, health services use, preventive practices and disability and mental health disorders at the initial time and it was not assessed again. 10,000 subjects randomly selected in a multi-stage sampling strategy were interviewed, and from them, only subjects 45 years old and more were included for follow-up in our study, giving a total of 4,465 subjects. The vital status was established by linkage with the Barcelona Mortality Register for each year from 2000 to 2008. We will analyze the data using Cox proportional hazard regression models to estimate the hazard ratios of death and 95% confidence intervals (total mortality) for physical activity.

The Barcelona Health Interview Survey Follow-Up Study

The inception cohort was a representative sample of the non-institutionalized population of Barcelona in year 2000, with information on socio-demographic factors, chronic conditions, life styles (including PA), self-perceived health, health services use, preventive practices and disability and mental health disorders at baseline Details on subject recruitment and procedures are described elsewhere.[66, 67] In brief, the survey included 10,000 subjects randomly selected in a multi-stage sampling strategy: the sample strata were the 10 districts of the city and, in each stratum, a random sample of residents was obtained, the sample unit being the individual. The information was collected during face-to-face interviews at home, between February 2000 and March 2001. Interviews were conducted in Catalan and Spanish. The interviewer could be helped by a proxy person in case the index person did not understand the language or had communication problems.

Main Outcome measure: Total (all-cause) mortality was the main outcome measure as recorded in the Barcelona Mortality Register. Given the limited number of deaths, we disregarded the analysis by specific causes of death. *Independent variables*: We considered separately leisure time physical activity and occupational (i.e., work-related) physical activity, from physical activities recalled during the last 2 weeks before the interview. Also, we included walking practice considering cumulative hours of walking per 2 weeks of walking.

Questions on leisure time physical activity were adapted from those used in the Welsh Heart Health Study (asking for the activities done, how many times and how many minutes). These questions have been successfully used in the same population and have a high correlation with physical fitness. Thus, leisure time physical activities from the questionnaire were defined in multiples of the metabolic equivalents (METs, kcal/kg*h) and were obtained from a compendium of physical activities. Total energy expended in METs was estimated from reported time and frequency of each activity in the past 2 weeks. Total energy expended in METs was categorized according to quartiles (in women, sedentary: ≤ 243; low: 243.1 to 1,408; moderate: 1,408.1 to 3,157.9; and high: ≥3,158; in men: sedentary:≤795.9; low: 796 to 2,026.9; moderate: 2,027 to 4,319.9; high: ≥4,320;). Occupational physical activity was assessed with the question: "Which of the following possibilities best describes your usual activity at work, home or in study place (excluding sports and leisure-time physical activity)? that admitted the following answers: 1) sitting down most of the day; 2) standing most of the day, with little movement or exertions of energy; 3) walking, carrying some weight, frequent movement; and 4) physical effort and heavy labor. These categories were labeled as *sedentary, low, moderate and high* occupational physical activity, respectively.

Cumulative hours per 2 week of walking habits recalled from the questionnaire during the last 2 weeks (number of times and minutes each time) before the interview were assessed, then no-walking and amount of walking were graded in three levels according to its frequency (1st third: 0.5 to 6; 2nd third:6.6 to 15; 3rd : third > or equal 16). The other independent variables included socio-demographic determinants such as sex, age (45-54 years; 55-64 years; 65-74 years; ≥75 years), maximum educational level attained (less than primary or primary studies; secondary or university studies) and social class based on occupation. Social class was obtained using the Spanish adaptation of the British Registrar General classification, through the current of past occupation of the interviewed or, if she/he had never worked, the occupation of the head of the household. We also used working status according to main activity (employed; unemployed; disabled or retired; student; housewife). The following life style were included as potential confounders: smoking (never

smokers; former smoker; current smokers), alcohol consumption (nondrinkers and sex-specific thirds of consumption in g/day), and health-related variables: number of chronic conditions (0; 1 and ≥ 2); self-perceived health (recoded into two categories as “suboptimal” if subjects declared to have a “poor”, “ bad” or “very bad” health and as “optimal” if they declared to have a “good” or “very good” health) and body mass index (BMI) from self-reports on weight and height, calculated as weight/height squared (in Kg/m2). We categorized BMI as “obesity/overweight”, “regular” and “underweight” according to WHO recommendations for men and women.

Follow-up: We included the 4,465 subjects older than 45 for follow-up (2516 women and 1949 men). The vital status was established by linkage with the Barcelona Census Register, which is connected with the Catalan Mortality Register, for each year from 2000 to 2008. The beginning of the follow-up was established by the date of interview and the end of follow-up with the date of death for deceased subjects or the censoring date (August 30th, 2008). Migrants were censored at the date of migration, as recorded in the Census. We obtained 29,683 person-years of follow-up. Statistical procedures: Participants were classified by physical activity levels. We examined the distribution of covariates according to level of physical activity for women and men using the X^2 test to compare proportions and the analysis of variance to compare means. We used multivariate Cox proportional hazard regression models to estimate the hazard ratios (HR) of death and the corresponding 95% confidence intervals (CI) by level of physical activity while controlling for relevant covariates. We considered time on entry at the study (interview date) as the time scale. Physical activity was included in the models as a categorical variable, with the lower level of physical activity as the reference category. The proportional hazard assumption was assessed and confirmed with graphical methods, and with models including time-by-covariate interactions. To examine the potential for residual confounding of the age-adjusted estimates, we compared age-adjusted estimates and estimates adjusted for multiple confounding factors. We tested performed separated analysis for women and men. All the statistical analyses included the sample weights derived from the complex sample design.

PART 4

Results

4. Results

In order to assess the objectives, the thesis was carried out in 2 separates studies. These studies are presented into two scientific articles:

- **Article 1**: **Cornelio CI**, García M, Schiaffino A, Borrès JM, Nieto FJ, Fernández E; CHIS.FU Study Group. Changes in leisure time and occupational physical activity over 8 years: the Cornellà Health Interview Survey Follow-Up Study. *J Epidemiol Community Health*. 2008 Mar; **62**(3):239–44.

- **Article 2**: **Cornelio CI**, Fernández E, Marí-Dell'Olmo M, Borrell C. Physical activity and mortality in a prospective cohort of women and men in a Mediterranean population. Submitted

ARTICLE 1

Changes in leisure time and occupational physical activity over 8 years: the Cornellà Health Interview Survey Follow-Up Study

Cornelio CI, García M, Schiaffino A, Borrès JM, Nieto FJ,

Fernández E; CHIS.FU Study Group.

J Epidemiol Community Health. 2008; **62**(3):239–44.

doi:10.1136/jech.2006.051953

ARTICLE 2

Physical activity and mortality in a prospective cohort of women and men in a Mediterranean population

Cornelio CI, Fernández E, Marí-Dell'Olmo M, Borrell C

Submitted

ARTICLE 2

Physical activity and mortality in a prospective cohort of women and men in a Mediterranean population

Cecilia I. Cornelio[1, 2], Esteve Fernández[1, 3, 4 *], Marc Marí-Dell'Olmo[5, 6, 7], Carme Borrell[2, 5, 6, 7]

- Tobacco Control Unit, Cancer Control and Prevention Programme, Institut Català d'Oncologia-ICO. L'Hospitalet de Llobregat (Barcelona), Spain.
- Department of Exprimental and Life Sciences, School of Life Sciences, Universitat Pompeu Fabra, Barcelona (Spain).
- Department of Clinical Sciences, School of Medicine, Universitat de Barcelona, Carretera de la Feixa llarga s/n. 08908 L'Hospitalet del Llobregat (Barcelona), Spain.
- Cancer Control and Prevention Group, Institut d'Investigació Biomèdica de Bellvitge-IDIBELL, L'Hospitalet de Llobregat (Barcelona), Spain.
- Agència de Salut Pública de Barcelona, Barcelona, Barcelona, Spain.
- CIBER Epidemiología y Salud Pública (CIBERESP), Spain.
- Institut d'Investigació Biomèdica (IIB Sant Pau). Barcelona, Spain.

* **Corresponding author**:
Dr. Esteve Fernández, Tobacco Control Unit, Cancer Control and Prevention Programme, Institut Català d'Oncologia-ICO. Av. Gran Via de l'Hospitalet 199-203, 08908 L'Hospitalet de Llobregat (Barcelona), Spain. E-mail: efernandez@iconcologia.net

ABSTRACT

- **Background** To analyze the association of different physical activity domains with overall mortality in a population-based cohort of women and men in a Mediterranean population.

- **Method** Baseline data from 10,000 subjects randomly selected from the population of Barcelona in a multi-stage sampling strategy was collected between February 2000 and March 2001. Subjects ≥45 years old were included for follow-up, obtaining a total of 4,465 participants (2,516 women and 1,949 men). The vital status was established by linkage with the Barcelona Mortality Register up to 2008. To determine the association between all-cause mortality and domains of physical activity, crude mortality rates per 1,000 persons-years and hazard ratios (HR) with 95% confidence intervals (CI) were computed.

- **Results** There were 694 deaths (355 women and 339 men) during the 6.6-years follow-up. Leisure time physical was inversely associated to the risk of death with a 60% reduction in the more active women (HR=0.40, 95% CI 0.27- 0.60) and men (HR=0.60, 95% CI 0.27-0.78). The multivariate analysis showed similar figures. Walking habit was associated with decreased mortality which was stronger among women. An inverse trend in mortality is also apparent for occupational physical activity.

- **Conclusion** The effects of all domains of physical activity were substantial; therefore promoting moderate levels of Leisure Time Physical Activity, Occupational Physical Activity and walking should be essential in comprehensive health promotion programs.

- **Keywords** Physical activity, mortality, cohort study, leisure time, occupation

Introduction

There is a huge body of evidence and agreement, both from a preventive and a rehabilitative viewpoint, that regular physical activity results in positive health-related outcomes, including reduction of all-cause-mortality.[1-4] An association of leisure time physical activity with overall mortality, with active persons having a longer life expectancy has been shown in different studies -mostly in Anglo-Saxon contexts.[5-8] However it is not clear whether other domains of physical activity, such as occupational and daily commuting or walking are associated with lower risk of disease and death.[9-11]

Most of the studies on PA and mortality to date have been conducted among selected population groups[12-16] and, moreover, there is scant evidence about those effects among women.[17- 19] Hence, prospective studies in representative samples of the general population can help to assess the public health impact of physical activity as well as to estimate the relative risk of death associated to different dimensions and levels of physical activity. In addition, a joint effect between a healthy lifestyle and the process of healthy living are likely to occur; therefore, major determinants must be studied simultaneously.[20, 21]

Cumulated evidence relating to the health benefits of increasing PA has resulted in guidelines that emphasizes the utility of the "physical exercise" approach,[22-24] and promoting heart-healthy behaviours is a major strategy to reduce the development of cardiovascular disease, among other disorders.[25] Despite increasing awareness and commitment concerning these issues, the United Nations have voiced their ongoing concern about the increase in non-communicable diseases which are now responsible for more deaths than all other causes combined, pointing out that physical activity is one of the few proven and affordable measures to prevent this fatal outcome. [26, 27] Therefore, understanding the balance of sedentarism trends and activity patterns in each community is fundamental to prevent adverse health consequences or delayed onset of non-communicable diseases from a contemporary perspective.[28]

Consequently, this paper analyzes separately, for women and men, the association of different physical activity domains with

overall mortality in a population-based cohort in a Mediterranean population.

Methods

Study subjects

We used data from the Barcelona Health Interview Survey Follow-Up Study. The inception cohort was a representative sample of the non-institutionalized population of Barcelona in year 2000, and collected socio-demographic information about chronic conditions, life styles (including PA), self-perceived health, health services use, preventive practices and disability and mental health disorders at baseline Details on subject recruitment and procedures are described elsewhere.[29, 30] In brief, the survey included 10,000 subjects randomly selected in a multi-stage sampling strategy: the sample strata were the 10 districts of the city and, in each stratum, a random sample of residents was obtained, the sample unit being the individual. The information was collected in face-to-face interviews at home, between February 2000 and March 2001. Interviews were conducted in Catalan and Spanish. The interviewer could be helped by a proxy person in case the index person did not understand the language or had communication problems.[31]

Main Outcome measure

Total (all-cause) mortality was the main outcome measure as recorded in the Barcelona Mortality Register. Given the limited number of deaths, we disregarded the analysis by specific causes of death.

Independent variables

We considered separately leisure time physical activity and occupational (i.e., work-related) physical activity, from physical activities recalled during the last 2 weeks before the interview. Also, we included walking practice considering cumulative hours of walking per 2 weeks of walking.

Questions on leisure time physical activity were adapted from those used in the Welsh Heart Health Study (asking for the activities done, how many times and how many minutes).[32, 33] These questions have been successfully used in the same population and have a high correlation with physical fitness.[34-37] Thus, leisure time physical activities from the questionnaire were defined in multiples of the metabolic equivalents (METs, kcal/kg*h) and were obtained from a compendium of physical activities.[38] Total energy expended in METs was estimated from reported time and frequency of each activity in the past 2 weeks. Total energy expended in METs was categorized according to quartiles (in women, sedentary: ≤ 243; low: 243.1 to 1,408; moderate:1,408.1 to 3,157.9; and high: ≥3,158; in men: sedentary:≤795.9; low: 796 to 2,026.9; moderate: 2,027 to 4,319.9; high: ≥4,320;). Occupational physical activity was assessed with the question: "Which of the following possibilities best describes your usual activity at work, home or in study place (excluding sports and leisure-time physical activity)? that admitted the following answers: 1) sitting down most of the day; 2) standing most of the day, with little movement or exertions of energy; 3) walking, carrying some weight, frequent movement; and 4) physical effort and heavy labor. These categories were labeled as sedentary, low, moderate and high occupational physical activity, respectively.

Cumulative hours per 2 week of walking habits recalled from the questionnaire during the last 2 weeks (number of times and minutes each time) before the interview were assessed, then no-walking and amount of walking were graded in three levels according to its frequency (1st third: 0.5 to 6; 2nd third:6.6 to 15; 3rd : third > or equal16).

The other independent variables included socio-demographic determinants such as sex, age (45-54 years; 55-64 years; 65-74 years; ≥75 years), maximum educational level attained (less than primary or primary studies; secondary or university studies) and social class based on occupation. Social class was obtained using the Spanish adaptation of the British Registrar General classification, through the current of past occupation of the interviewed or, if she/he had never worked, the occupation of the head of the household.[39, 40] We also used working status according to main activity (employed;

unemployed; disabled or retired; student; housewife). The following life style were included as potential confounders: smoking (never smokers; former smoker; current smokers), alcohol consumption (non drinkers and sex-specific thirds of consumption in g/day), and health-related variables: number of chronic conditions (0; 1 and ≥ 2); self-perceived health (recoded into two categories as "suboptimal" if subjects declared to have a "poor", " bad" or "very bad" health and as "optimal" if they declared to have a "good" or "very good" health) and body mass index (BMI) from self-reports on weight and height, calculated as weight/height squared (in Kg/m2). We categorized BMI as "obesity/overweight", "regular" and "underweight" according to WHO recommendations for men and women.[41]

Follow-up

We included the 4,465 subjects older than 45 for follow-up (2516 women and 1949 men). The vital status was established by linkage with the Barcelona Census Register, which is connected with the Catalan Mortality Register, for each year from 2000 to 2008. The beginning of the follow-up was established by the date of interview and the end of follow-up with the date of death for deceased subjects or the censoring date (August 30th, 2008). Migrants were censored at the date of migration, as recorded in the Census. We obtained 29,683 person-years of follow-up.

Statistical procedures

Participants were classified by physical activity levels. We examined the distribution of covariates according to level of physical activity for women and men using the X^2 test to compare proportions and the analysis of variance to compare means.

We used multivariate Cox proportional hazard regression models to estimate the hazard ratios (HR) of death and the corresponding 95% confidence intervals (CI) by level of physical activity while controlling for relevant covariates. We considered time on entry at the study (interview date) as the time scale. Physical activity was included in the models as a categorical variable, with the lower level of physical activity as the reference category. The

proportional hazard assumption was assessed and confirmed with graphical methods, and with models including time-by-covariate interactions[42] To examine the potential for residual confounding of the age-adjusted estimates, we compared age-adjusted estimates and estimates adjusted for multiple confounding factors. We tested performed separated analysis for women and men. All the statistical analyses included the sample weights derived from the complex sample design. All procedures were carried out with STATA (StataCorp 4905 Lakeway Drive College Station, Texas 77845 USA) version 9.

Results

There were 694 deaths (355 women and 339 men) during the study period, with a median follow-up of 6.7 years for women and 6.5 for men. Tables 1 and 2 show the mean age values and distribution of potential confounders and socio-demographic variables at baseline, by levels of leisure time physical activity, occupational physical activity and walking.

The high performers of leisure time physical activity and occupational physical activity compared with sedentary participants tended to be younger, in both women and men. Differences between leisure time physical activity and occupational physical activity were seen in educational and social class terms: moderate and high leisure time physical activity participants had a higher education and were in advantaged social classes, both in women and men. Conversely, women and men with moderate/ high occupational physical activity were less educated.

There were significant differences in the levels of PA attributable to walking according to other lifestyle and socio-demographic variables. In general, male participants in the two most active groups (upper thirds) had less education, were in disadvantage social classes and were older. Minor differences were seen among women across thirds of walking categories.

Tables 3 and 4 show the number of deaths, the crude mortality rates and the HRs and 95% CIs of death, according to leisure time physical

activity, walking and occupational physical activity, for women and men respectively.

Leisure time physical activity was inversely associated to the risk of death. In the case of women, a reduction of mortality was observed across levels of leisure time physical activity, with a clear linear trend (p for trend < 0.001), getting a 60% reduction in the more active women (age-adjusted HR=0.40, 95%CI 0.27 to 0.60) when compared with sedentary. This pattern remained after adjustment for several potential confounders (table 3). The protective effect of walking was also evident among women, with a 59% reduction of mortality risk and a clear dose-response relationship (p for trend < 0.0001). Men with high leisure time physical activity habits had an age-adjusted HR of death of 0.57, 95%CI 0.41 to 0.79). The multivariate analysis showed similar figures, confirming the significant protective effect of high leisure time physical activity whereas a linear trend in the HR was not apparent. The analysis of walking habits showed a trend towards reduction of mortality as the amount of walking increases, up to a 33% of reduction when observing the highest performing group (multivariate HR 0.67, 95%CI 0.48 to 0.95).

An inverse trend in mortality was also apparent for occupational physical activity. In women, age-adjusted mortality risk and multivariate analysis show a statistically significant protective effect upon mortality: for those women who were physically more active, the risk of all-cause mortality was 39% lower than for those who were physically inactive (multivariate HR 0.61; 95%CI 0.41 to 0.93). In men, a pattern towards reduced mortality was also present, whereas the mortality risk reduction was less than that observed in women.

Discussion

Our data show that PA, anyway analyzed as leisure time physical activity, walking habits and occupational physical activity, is clearly associated with lower risk of all-cause mortality in both women and men. One of the key findings is that PA was related to all-cause mortality risk with a dose–response pattern (more pronounced in women than in men) as verified in other populations, according to other authors' findings.[43-46]

Even though walking habits and occupational physical activity have been shown to be inversely associated with all-cause mortality in this representative sample of general population, the published evidence of such an association in terms of gender and physical activity intensity is not well established.[47, 48] Sundquist *et al*.[49] demonstrate that even occasional physical activity is associated with decreased all-cause mortality and insist on the benefits of walking in the elderly. Other studies have found that regular walking among older men participating was also associated with decreased all-cause mortality.[50, 51] Moreover, our study shows that even low amount of walking in both women and men, middle aged and over, is associated with decreased all-cause mortality. In contrast, data from the Seventh Day Adventist Study revealed only a small effect of physical activity on mortality for men, although relevant for men aged 65 to 74 at the start of the study.[52]

Regarding occupational physical activity, conflicting results characterize the available scientific evidence. In some studies, high levels of occupational physical activity have been reported to reduce the risk of cardiovascular and all-cause mortality.[53] In contrast, other studies have reported an increased risk of cardiovascular disease and premature mortality resulting from a high level of occupational physical activity.[54] This divergence might be due to a number of reasons, including discrepancies in the assessment of physical activity at work, differences between the study populations, or work groups, the length of follow-up, and lack of potential confounders control.

This paper adds epidemiological evidence in support of the physical activity amount accumulation hypothesis through an “active living” (based on diverse activities, such as walking, occupation, housework or fitness) for improving health gains. These results also contribute to the understanding of the epidemiology of the activity-sedentarism binomium. All aspects of daily life and their impacts on population health outcomes must be considered for a clear understanding of the new paradigm in activity-inactivity research.[19, 55]

Taking into account that public recommendations for health-promoting physical activity[17] do not discriminate between activities

occurring at the workplace, in daily life or during leisure time, our data emphatically stresses the importance of health effects of walking. Why is this significant? Our society is experimenting increasing levels of technological development and potential increase of passive tasks, as reflected in trends in life expectancy and alarming increases in levels of obesity around the world.[56] Thus, it is highly unlikely that mere recommendations of moderate leisure time physical activity – also extremely difficult to achieve and sustain- will suffice to prevent increasing burden of chronic diseases in the population and to restore the balance between activity and sedentarism, as proposed by some researchers.[28] Therefore, walking is the most accessible tool to achieve this goal.

Although randomized controlled trials provide the strongest form of scientific evidence of physical activity intervention effectiveness, one of the most significant strengths of this observational cohort study is that it captures the variation of the community daily living. This study also includes a representation of what happens in the general population, a limitation when studying samples recruited in randomized controlled trials or in selected population groups.[57] Furthermore, to our knowledge, this investigation is the first one of its class in a Mediterranean population.

However, potential limitations have to be considered. Participants selected for this analysis were adults over 45, thus the present findings cannot be generalized to younger ages, while levels of physical activity among younger people are even higher.[26, 27] Although we used self-reports to assess physical activity, such information has been considered to be reliable and valid.[20-24] The present analysis controlled for major potential confounding variables, but residual confounding cannot be ruled out. All study variables were measured at baseline, and no repeated measures were considered in the design of the study. Hence, changes in the levels of physical activity and other variables might affect the results. A tendency to increase the levels of leisure time physical activity during the last decades in Spain has been described, as well as other healthy life styles, whereas obesity and overweight have increased.[58, 59] Given that almost all potential changes would have been favourable in terms of health gain; our results, if biased,

would be an underestimation of the real impact of physical activity upon mortality.

In conclusion, this cohort study shows that low and moderate levels of physical activity are associated with a reduction of all-cause mortality risk among both women and men and, furthermore, that there is a noticeable protective trend in women. This protective effect was observed after controlling for other mortality determinants, such as age, BMI, education, smoking and other health and social conditions.

Therefore, promoting moderate levels of leisure time physical activity, including walking, and occupational physical activity, should be an essential component in comprehensive health promotion programmes for the primary prevention of non-communicable diseases.

Acknowledgements

Cecilia Cornelio received a Doctoral Fellowship of the Alβan Programme (E04D045892AR). EF was partly funded by the Instituto de Salud Carlos III (RTICC RD12/0036/0053) and the Department of Universities and Research, Government of Catalonia (grants 2009SGR192).

Competing interest: None.

References

[1] Pekkanan J, Marti B, Nisinen A *et al*. Reduction of premature mortality by high physical activity: a 20-year follow-up of middle-aged Finnish men. *Lancet* 1987;**1**:1473–7.

[2] Johansson SE, Sundquist J. Change in lifestyle factors and their influence on health status an all-cause mortality. *Int J Epidemiol* 1999; **28**:1073–80.

[3] Nusselder W, Franco O, Peeters A, Mackenbach J. Living healthier for longer: Comparative effects of three heart-healthy behaviors on life expectancy with and without cardiovascular disease. *BMC Public Health* 2009; **9**:487.

[4] Holmes MD, Chen WY, Hankinson SE, Willett WC. Physical activity's impact on the association of fat and fiber intake with survival after breast cancer. *Am J Epidemiol* 2009; **170**:1250–6.

[5] Patel AV, Bernstein L, Deka A *et al*. Leisure time spent sitting in relation to total mortality in a prospective cohort of US adults. *Am J Epidemiol* 2010; **172**:419–29.

[6] Smith GD, Shipley MJ, Batty GD *et al*. Physical activity and cause-specific mortality in the Whitehall study. *Public Health* 2000; **114**:308–15.

[7] Myers J, Kaykha A, George S *et al*. Fitness versus physical activity patterns in predicting mortality in men. *Am J Med* 2004; **117**:912–8.

[8] Stamatakis E, Hamer M, Lawlor DA. Physical Activity, Mortality, and Cardiovascular Disease: Is Domestic Physical Activity Beneficial?: The Scottish Health Survey—1995, 1998, and 2003. *Am J Epidemiol* 2009; 169:1191–1200.

[9] Hamer M, Chida Y. Active commuting and cardiovascular risk: A meta-analytic review. *Prev Med* 2008; **46**:9–13.

[10] Woodcock J, Franco OH, Orsini N, Roberts I. Non-vigorous physical

activity and all-cause mortality: systematic review and meta-analysis of cohort studies. *Int J Epidemiol* 2011; **40**:121–138.

[11] Andersen LB, Schnohr P, Scroll M, Hein HO. All- cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. *Arch Intern Med* 2000; **160**:1621–8.

[12] Byberg L, Melhus H, Gedeborg R *et al*. Total mortality after changes in leisure time physical activity in 50 year old men: 35 year follow-up of population based cohort. *BMJ* 2009; **338**:b688.

[13] Paffenbarger RS Jr, Hyde RT, Wing AL, Hsieh CC. Physical activity, all-cause mortality, and longevity of college alumni. *N Engl J Med* 1986; **314**:605–13.

[14] Paffenbarger RS Jr, Hyde RT, Wing A.L *et al*. The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. *N Engl J Med* 1993; **328**:538–545.

[15] Paffenbarger RS Jr, Kampert J, Lee IM, *et al*. Changes in physical activity and other life way patterns influencing longevity. *Med Sci Sports Exerc* 1994; **26**:857–65.

[16] Blair SN, Kohl HW, Barlow C.E. *et al*. Changes in physical fitness and all-cause mortality. A prospective study of healthy and unhealthy men. *JAMA* 1995; **273**:1093–8.

[17] Baer HJ, Glynn RJ, Hu FB *et al*. Risk factors for mortality in the nurses' health study: a competing risks analysis. *Am J Epidemiol* 2011; **173**:319–29.

[18] Lissner L, Bengtsson C, Björkelund C, Wedel H. Physical activity levels and changes in relation to longivity: a prospective study of Swedish women. *Am J Epidemiol* 1996; **143**:54-62.

[19] Trolle-Lagerros Y, Mucci L, Kumle M *et al*. Physical Activity as a Determinant of Mortality in Women. *Epidemiology* 2005; **16**:780–5.

[20] van Dam RM, Li T, Spiegelman D *et al*. Combined impact of lifestyle

factors on mortality: prospective cohort study in US women. *BMJ* 2008; **337**:a1440.

[21] Kvaavik E, Batty GD, Ursin G *et al*. Influence of individual and combined health behaviors on total and cause-specific mortality in men and women: the United Kingdom health and lifestyle survey. *Arch Intern Med* 2010; **170**:711–8.

[22] Haskell WL, Lee IM, Pate RP *et al*. Physical activity and public health: updated recommendation for adults from the American College of Sport Medicine an the American Heart Association. Circulation 2007; **116**:1081–93.

[23] U.S. Department of Health and Human Services. Physical Activity Guidelines Advisory Committee Report 2008. Washington, D.C, 2008 http://www.health.gov/paguidelines/report/pdf/committeereport.pdf (accessed 4th December 2013)

[24] U.S. Department of Health and Human Services. The Surgeon General's Vision for a Healthy and Fit Nation. Rockville, MD: U.S. Department of Health and Human Services, Office of the Surgeon General, 2010.

[25] US Department of Health and Human Services: Healthy People Understanding and Improving Health Volume I-II.2nd edition. Washington D.C, 2010.

[26] United Nations. Prevention and control of non-communicable diseases. Report of the Secretary General, 2011. http://www.un.org/en/ga/president/65/issues/A-RES-65-238.pdf, and http://www.un.org/ga/search/view_doc.asp?symbol=A/66/L.1 (accessed on 4th December 2013)

[27] Alwan A, MacLean DR, Riley LM, *et al*. Monitoring and surveillance of chronic non-communicable diseases: progress and capacity in high burden countries. *Lancet* 2010; **376**:1861–8.

[28] Brown WJ, Bauman AE, Owen N. Stand up, sit down, keep moving: turning circles in physical activity research? Br J Sports Med

2009;43:86–8.

[29] Borrell C, Baranda L, Rodriguez M. Manual de l'enquesta de salut de Barcelona 2000. Barcelona: Institut Municipal de Salut Pública, 2002

[30] Borrell C, Muntaner C, Solà J *et al*. Immigration and self-reported health status by social class and gender: the importance of material deprivation, work organisation and household labour. *J Epidemiol Community Health* 2008 May; **62**:e7.

[31] Borrell C, Baranda L, Rodríguez M. Manual de l'enquesta de salut de Barcelona 2000. Barcelona: Institut Municipal de Salut Pública; 2002.

[32] Pereira MA, Fitzer Gerald SJ, Gregg EW, *et al*. A collection of physical activity questionnaires for health-related research. *Med Sci Sports Exerc* 1997; **29**(6 Suppl):S1–S205.

[33] Health Promotion Authority for Wales. Heart of Wales: clinical results of the Welsh Heart Health Survey 1985. *Cardiff: Health Promotion Authority for Wales* 1989.

[34] Weiss TW, Slater CH, Green LW, *et al*. The validity of single-item, self-assessment questions as measures of adult physical activity. *J Clin Epidemiol* 1990; **43**:1123–9.

[35] Dominguez-Berjon MF, Borrell C, Nebot M *et al*. Physical activity assessment in population surveys: can it really be simplified? *Int J Epidemiol* 1999; **28**:53–7.

[36] Dominguez-Berjon MF, Borrell C, Nebot M *et al*. La actividad física de ocio y su asociación con variables sociodemográficas y otros comportamientos relacionados con la salud. *Gac Sanit* 1998; **12**:100–9.

[37] Dominguez-Berjon MF, Borrell C, Nebot M *et al*. Actividad física habitual de la población residente en la ciudad de Barcelona. Gac Sanit 1998; **12**:110–7.

[38] Ainsworth BE, Haskell WL, Whitt MC *et al*. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000; **32**(9 Suppl):S498–504.

[39] Muntaner C, Borrell C, Benach J *et al*. The associations of social class and social stratification with patterns of general and mental health in a Spanish population. *Int J Epidemiol* 2003; **32**:950–8.

[40] Álvarez-Dardet, C, Alonso, J, Domingo, A., Regidor, E., coord. La medición de la clase social en ciencias de la salud. Barcelona: SG-Editores, Sociedad Española de Epidemiología; 1995.

[41] Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation. *World Health Organ Tech Rep Ser* 2000; **894**:i-xii:1–253.

[42] Cox DR. Regression models and life tables (with discussion). *J Roy Statist Soc B* 1972; **34**:187–220.

[43] Thune I, Furberg AS. Physical activity and cancer risk:dose-response and cancer, all sites and site-specific. *Med Sci Sports Exerc* 2001; **33**(6 suppl):S530–50.

[44] Takahashi H; Kuriyama S; Tsubono Y *et al*. Time spent walking and risk of colorectal cancer in Japan: The Miyagi Cohort Study. *Eur J Cancer Prev* 2007; **16**: 403–408.

[45] Oguma Y, Sesso HD, Paffenbager RS jr, Lee IM. Physical activity and all-cause mortality in women: a review of the evidence. *Br J Sports Med* 2002; **36**:162–72.

[46] Samitz G, Egger M, Zwahlen M. Domains of physical activity and all cause mortality: systematic review and meta-analysis of cohort studies. *Int J Epidemiol* 2011; **40**:1382–400.

[47] Schnohr P, Scharling H, Jensen J. Intensity versus duration of walking, impact on mortality: the Copenhagen City Heart Study. *Eur J Cardiovasc Prev Rehabil* 2007; **14**:72–78.

[48] Orsini N, Mantzoros CS, Wolk A. Association of physical activity with cancer incidence, mortality ,and survival: a population-based study of men. *Br J Cancer* 2008; **98**:1864–9.

[49] Sundquist K, Qvist J, Sundquist J, Johansson SE. Frequent and Occasional Physical Activity in the Elderly: A 12-Year Follow-up Study of Mortality. *Am J Prev Med* 2004; **27**:22–7.

[50] Hakim AA, Petrovitch H, Burchfiel CM, *et al*. Effects of walking on mortality among nonsmoking retired men. *N Engl J Med* 1998; **338**:94–9.

[51] Landi F, Russo A, Cesari M *et al*. Walking one hour or more per day prevented mortality among older persons: Results from ilSIRENTE study. *Prev Med* 2008; **47**:422–6.

[52] Lindsted KD, Tonstad S, Kuzma JW. Self-report of physical activity and patterns of mortality in Seventh-Day Adventist men. *J Clin Epidemiol* 1991; **44**:355–64.

[53] Holtermann A, Mortensen OS, Burr H *et al*. The interplay between physical activity at work and during leisure time risk of ischemic heart disease and all-cause mortality in middle-aged Caucasian men. *Scand J Work Environ Health* 2009; **35**:466–74.

[54] Raum E, Rothenbacher D, Ziegler H, Brenner H. Heavy physical activity: risk or protective factor for cardiovascular disease? A life course perspective. *Ann Epidemiol* 2007; **17**:417–24.

[55] Vartiainen E, Laatikainen T, Peltonen M *et al*. Thirty-five-year trends in cardiovascular risk factors in Finland. *Int J Epidemiol* 2010; **39**: 504–18.

[56] Leon DA. Editorial: trends in European Life expectancy: a salutary view. *Int J Epidemiol* 2011; **40**:271–7.

[57] de Groot LC, Verheijden MW, de Henauw S *et al*. Lifestyle, nutritional status, health, and mortality in elderly people across Europe: a review of the longitudinal results of the SENECA study. *J*

Gerontol A Biol Sci Med Sci 2004; **59**:1277-84.

[58] Cornelio CI, Garcia M, Schiaffino A *et al*. Changes in leisure time and occupational physical activity over 8 years: the Cornella Health Interview: Survey Follow-Up Study. *J Epidemiol Community Health* 2008; **62**:239–44.

[59] Regidor E, Gutiérrez-Fisac JL, de los Santos Ichaso M, Fernández E. Trends in principal cancer risk factors in Spain. *Ann Oncol* 2010; **suppl3**:iii37–42.

Table 1. Baseline (year 2000) characteristics of female participants according to physical activity levels.

	All Female *n*=2516	Leisure Time Physical Activity*				Walking# (cumulative hours in 2 weeks)				Occupational Physical Activity			
		Sedentary n=752	Low n=633	Moderate n=579	High n=429	No n=576	1st third n=720	2nd third n=816	3rd third n=281	Sedentary n= 702	Low n=947	Moderate n=451	High n=72
Age (mean, SD)	64, (12.0)	67,11.3	63, 10.0	59, 9.7	58, 9.9	65.2, 12.7	62.0, 11	63.6, 11.3	64.9, 11	67.0, 12.3	63.0, 10	59.9, 9.7	59.0, 9
Education (% University studies)	**9.62**	6.25	12.6	10.3	12.2	6.8	11.9	10.4	10.3	13.5	11.2	10.2	8.8
Social Class (% of I-II)	**12.3**	10.3	13.9	14.0	13.1	10.3	13.9	12.8	12.0	11.7	11.8	14.2	16.7
BMI (% of Normal)	**41**	36.2	45.1	42.2	42.3	38.3	42.5	43.4	36.6	35.7	45.6	41.0	39.3
Self perceive health (% of optimal)	**59.8**	45.6	59.6	60.1	57.4	44.6	61.3	57.9	51.6	54.6	60.6	64.3	60.5
Chronic Conditions (% of No conditions)	**16.3**	9.3	15.7	14.1	11.9	8.9	14.7	14.7	9.6	10-3	14.0	14.0	12.2
Alcohol consumption (% of No drinkers)	**48.8**	58.2	50.1	46.6	44.6	59.2	47.9	47.7	50.2	57.7	49.0	41.9	51.3
Smoking habit (% of Never smokers)	**79.5**	81.1	79.6	78.2	78.8	79.1	78.6	79.3	82.9	80.5	80.8	74.7	80.5

* Leisure Time Physical activity in thirds of cumulative 2 weeks of energetic index evaluated by METs/ duration/ frequency: Sedentary: ≤ 243; low: 243.1 to 1,408; moderate: 1,408.1 to 3,157.9; and high: ≥3,158;

Cumulative hours in 2 weeks of walking habits evaluated in thirds and No walking: 1st: 0.5-6; 2nd:6.6-15; 3rd:16-60.

Table 2. Baseline (year 2000) characteristics of male participants according to physical activity levels.

	All Male	Leisure Time Physical Activity*				Walking# (cumulative hours in 2 weeks)				Occupational Physical Activity			
	n=1949	Sedentary n=388	Low n=477	Moderate n=442	High n=569	No n=328	1st third n=524	2nd third n=816	3rd third n=281	Sedentary n=648	Low n=791	Moderate n=273	High n=112
Age (mean, SD)	**62 , 11.0**	67,11.3	63, 10.0	59, 9.7	58, 9.9	60.8, 11.7	58.1, 10	62.1, 19.7	64.8, 9.5	61.9, 11	63.0, 10	57.1,19	58.0, 9.1
Education (% University studies)	**21.2**	16	24.7	24.6	20.7	19.2	27.7	24.0	12.9	29.0	18.0	22.6	7.14
Social Class (% of I-II)	**21.8**	7.6	24.1	23.7	22.0	21.0	26.9	22.8	15.9	28.4	19.5	22.0	6.3
BMI (% of Normal)	**46.0**	51.0	43.0	59.0	63.3	52.2	60.0	61.0	60.7	57.4	60.6	59.9	54.9
Self perceive health (% of optimal)	**61.2**	61.0	67.0	70.0	68.0	64.0	70.5	69.7	62.5	62.0	59.0	69.0	62.8
Chronic Conditions (% of No conditions)	**15.8**	21.1	26.8	21.9	17.5	20.1	27.7	22.2	14.8	19	25.2	20.9	19.5
Alcohol consumption (% of No drinkers)	**25.9**	27.2	27.7	23.6	26.0	26.7	23.6	25.3	29.9	26.5	26.5	26.0	21.8
Smoking habit (% of Never smokers)	**27.1**	26.8	29.9	23.9	27.1	26.5	30.8	24.9	26.2	26.9	26.0	29.0	34.0

* Leisure Time Physical activity in thirds of cumulative 2 weeks of energetic index evaluated by METs/ duration/ frequency: Sedentary: ≤795.9; low: 796 to 2,026.9; moderate: 2,027 to 4,319.9; high: ≥4,320

Cumulative hours in 2 weeks of walking habits evaluated in thirds and No walking: 1st: 0.5-6; 2nd:6.6-15; 3rd:16-90.

Table 3. Hazard ratios∞ (*HR*) of All-cause mortality according to Physical Activity levels among women.

	Person- years of observations	Number of death	Crude rates	Age-adjusted *HR* *(95% CI)*	Multivariate adjusted *HR* *(95% CI)*
Leisure Time Physical Activity*		**280**			
Sedentary	5,209.1	125	23.9	**1**	**1**
Low	4,499.2	66	14.7	**0.72 (0.52 0.94)**	**0.70 (0.52 0.97)**^
Moderate	4,236.7	57	13.4	**0.56 (0.29 0.71)**	**0.58 (0.42 0.89)**
High	3,177.0	32	10.1	**0.40 (0.27 0.60)**	**0.42 (0.27 0.65)**
				p <0.001	*p <0.001*
Walking habits#		**329**			
No	3,622.9	74	20.4	**1**	**1**
1st third	4,880.3	84	17.8	**0.62 (0.45 0.84)**	**0.62 (0.46 0.86)**Ç
2nd third	5,701.2	116	20.3	**0.57 (0.42 0.76)**	**0.57 (0.43 0.72)**
3rd third	2,734.3	52	19.0	**0.40 (0.25 0.62)**	**0.41 (0.26 0.64)**
				p <0.0001	*p <0.0001*
Occupational Physical Activity		**275**			
Sedentary	5,513.95	150	27.2	**1**	**1**
Low	7,374.04	86	11.6	**0.53 (0.41 0.70)**	**0.58 (0.43 0.78)**±
Moderate/ High	3,949.68	38	9.2	**0.63 (0.44 0.90)**	**0.61 (0.41 0.93)**
				p =0.005	*p =0.005*

* Leisure Time Physical activity in thirds of cumulative 2 weeks of energetic index evaluated by METs: Sedentary: ≤ 243; low: 243.1 to 1,408; moderate: 1,408.1 to 3,157.9; and high: ≥3,158

Cumulative hours per 2 week of walking habits evaluated in thirds and No walking: 1st: 0.5-6; 2nd:6.6-15; 3rd:16-90

∞ By Cox regression analysis.

p values for X^2 linear test for trend.

^ Modeling by Cox regression analysis adjusted by age, education level and self perceive health.

± Modeling by Cox regression analysis adjusted by age and social class and self perceive health.

Ç Modeling by Cox regression analysis adjusted by age and education level and self perceive health.

Table 4. Hazard ratios∞ (*HR*) of All-cause mortality according to Physical Activity levels among men.

	Person-years of observations	Number of death	Crude rates	Age-adjusted *HR* *(95% CI)*	Multivariate adjusted *HR* *(95% CI)*
Leisure Time Physical Activity*		**301**			
Sedentary	2,663.1	71	26.6	**1**	**1**
Low	3,374.9	63	18.7	**0.78 (0.56 1.09)**	**0.80 (0.57 1.13)**^
Moderate	3,042.2	82	26.9	**0.90 (0.65 1.22)**	**0.90 (0.67 1.26)**
High	4,054.5	85	20.9	**0.57 (0.41 0.79)**	**0.60 (0.27 0.65)**
				p =0.08	*p =0.1*
Walking habits#		**323**			
No	2,709.3	69	25.5	**1**	**1**
1st third	3,761.9	92	24.4	**0.78 (0.54 1.09)**	**0.81 (0.56 1.10)**ç
2nd third	4,321.6	112	25.8	**0.85 (0.62 1.19)**	**0.88 (0.64 1.20)**
3rd third	2,141.7	50	23.3	**0.70 (0.50 0.98)**	**0.67 (0.48 0.95)**
				p =0.04	*p =0.05*
Occupational Physical Activity		**293**			
Sedentary	4,482,8	118	26.3	**1**	**1**
Low	5,613.5	134	23.8	**0.84 (0.66 0.98)**	**0.85 (0.65 0.99)**±
Moderate/High	2,749.7	41	149	**0.81 (0.57 1.19)**	**0.82 (0.55 1.18)**
				p =0.04	*p =0.05*

* Leisure Time Physical activity in thirds of cumulative 2 weeks of energetic index evaluated by METs/ duration/ frequency: Sedentary: ≤795.9; low: 796 to 2,026.9; moderate: 2,027 to 4,319.9; high: ≥4,320

Cumulative hours in 2 weeks of walking habits evaluated in thirds and No walking: 1st: 0.5-6; 2nd:6.6-15; 3rd:16-90.

∞ By Cox regression analysis.

p values for X^2 linear test for trend.

^ Modeling by Cox regression analysis adjusted by age, education level, tobacco use and BMI.

± Modeling by Cox regression analysis adjusted by age and social class and tobacco use.

Ç Modeling by Cox regression analysis adjusted by age, education level, alcohol consumption and self perceive health.

PART 5

Discussion

5. Discussion

The main results of this thesis are that there were changes at population levels on the physical activity status, and that no clear determinants of such changes were recognized. Moreover, the effects of all domains of physical activity considered -Leisure Time Physical Activity, Occupational Physical Activity and walking- were associated with a substantial decreased of mortality risk.

Regarding the changes in Physical activity (Article 1), we found that among our study participants, 61.6% of those reporting sedentary LTPA habits and 64.3% reporting sedentary OPA at baseline changed to more active levels 8 years later. These changes are consistent with reported trends of increasing LTPA in Mediterranean populations, despite the fact that populations have a high prevalence of obesity.[27, 68] Even though we could not identify clear correlates of changes in either LTPA or OPA in this community-based study, they appear to be more closely associated with socio-demographic factors than with other health conditions, related behaviours or lifestyle.

Although some studies[69-71] have linked the former factors with the likelihood of change of physical activity, many others have not.[72, 73] The lack of a statistically significant association between factors such as smoking habits and LTPA or self-perceived health and OPA are possibly affected by the relatively small sample size of the cohort. It is important to keep in mind, however, that we only explored associations between change in physical activity in association with baseline levels of these risk factors (that is, smoking, alcohol consumption, BMI, etc.), thus assuming that those factors remained unchanged during follow-up. Changes in these risk factors may affect changes in physical activity and, thus, this is a possible limitation of the study. Although we know that changes have occurred, we can't determine at which point in the follow-up these changes occurred, and hence we are not able to properly adjust for them in the analysis. However, our findings are in agreement with previously published results reporting no association or weak associations between changes in LTPA status and tobacco, alcohol consumption or obesity.[74] Our study focused mainly on the ''first step of change,'' from sedentary to light/

moderate LTPA, since sedentary subjects are those most critically needing some increase in physical activity.

Demographic factors, such as age and sex, were related to physical activity changes. Gender differences in reported LTPA levels were consistent with previous reports[75] and the association with age varied according to gender. Positive changes in LTPA were more likely in men than in women. Men reaching their 40s were more stable in their habits. Thus, targeting behavioural interventions to young men may have greater impact from a public health perspective. In this cohort, women were less likely to modify their physical activity habits, regardless of age.

Some authors have argued that decreasing OPA is one of the factors implicated in the steadily increasing prevalence of obesity in the developed world.[76, 77] In such societies, an increasing reliance on technology has considerably reduced work-related physical activity and the energy expenditure required for daily living. The circumstances in specific community settings such as ours with a unique social or cultural environment and economic organisation may lead to different relations between these social phenomena, however. The results of this study show that there were positive changes in OPA that could be attributable in part to changes in the overall pattern of occupation of the cohort: the proportion of employed people increased between 1994 (37.9%) and 2002 (48.7%); it is conceivable that those newly employed were in occupations with higher demands of OPA. Although an association of physical activity and social class has been reported by several authors,[29, 78, 79] the relative homogeneity of social class in our cohort (nearly 80% of the population belongs to social class categories IV and V) limited our ability to explore this issue. Nevertheless, we did observe some degree of association between education and changing physical activity habits especially in women. Educated and occupationally active women were more likely to increase their LTPA; furthermore employed women had greater tendency to be active in OPA terms. On the other hand, educated and older women had a greater probability to change to sedentary occupation-related physical activity. Therefore, this reveals some association between social class, education and occupation, as previously described in the literature.[80, 81]

Physical and social environment have been linked with increased physical activity.[47, 82] Community interventions[45, 83] to reduce sedentariness and to promote healthy habits have been proposed as primary health promotion activities. In addition, physical activity is ranked as a leading health indicator for future objectives of health improvement.[16] Several campaigns promoted walking and local community-sponsored wellness initiatives to promote exercise and to reduce cholesterol levels were developed in Cornellà de Llobregat during the late 1990s.[84] Whereas our objective did not focus on measuring the effectiveness of such activities, their impact could partially explain the magnitude of the observed changes in this population. Our design lacks repeated measures of physical activity at regular points of time that would have helped in evaluating a potential progressive increase in physical activity.

Complementary information, not only at the individual level but at contextual level (that is, number of fitness facilities in neighborhoods), should also be included in new studies aimed at assessing changes in physical activity. Available evidence suggests the benefits of a moderate amount of regular walking in improving wellbeing and cardiovascular fitness, while being easier to maintain than more demanding physical activity levels that have been recommended by international organisations.[85]

The campaigns in Cornella` de Llobregat were noticeable in positive effects on the exercise intention and walking behaviours of the cohort members: more than 50% of subjects who changed to sedentary and light/moderate physical activity declared walking as the preferred daily activity.

Concerning the association between physical activity and mortality (Article 2), our data show that PA, anyway analyzed as leisure time physical activity, walking habits and occupational physical activity, is clearly associated with lower risk of all-cause mortality in both women and men. One of the key findings is that PA was related to all-cause mortality risk with a dose–response pattern (more pronounced in women than in men) as verified in other populations, according to other authors' findings.[60, 62]

Even though walking habits and occupational physical activity have been shown to be inversely associated with all-cause mortality in this representative sample of general population, the evidence of such an association in terms of gender and physical activity intensity is not well established. Sundquist *et al* [86], demonstrate that even occasional physical activity is associated with decreased all-cause mortality and insist on the benefits of walking in the elderly. Other studies have found that regular walking among older men participating was also associated with decreased all-cause mortality. Moreover, our study shows that even low amount of walking in both women and men, middle aged and over, is associated with decreased all-cause mortality. In contrast, data from the Seventh Day Adventist Study revealed only a small effect of physical activity on mortality for men, although relevant for men aged 65 to 74 at the start of the study.[87]

Regarding occupational physical activity, conflicting results characterize the available scientific evidence. In some studies, high levels of occupational physical activity have been reported to reduce the risk of cardiovascular and all-cause mortality. In contrast, other studies have reported an increased risk of cardiovascular disease and premature mortality resulting from a high level of occupational physical activity. This divergence might be due to a number of reasons, including discrepancies in the assessment of physical activity at work, differences between the study populations, or work groups, the length of follow-up, and lack of potential confounders control.

This paper adds epidemiological evidence in support of the physical activity amount accumulation hypothesis through an “active living” (based on diverse activities, such as walking, occupation, housework or fitness) for improving health gains. These results also contribute to the understanding of the epidemiology of the activity-sedentarism binomium. All aspects of daily life and its impacts on population health outcomes must be considered for a clear understanding of the new pattern in activity-inactivity research.

Taking into account that public recommendations for health-promoting physical activity[44] do not discriminate between activities occurring at the workplace, in daily life or during leisure time, our data

emphatically stresses the importance of health effects of walking. Why is this significant? Our society is experimenting increasing levels of technological development and potential increase of passive tasks, as reflected in trends in life expectancy and alarming increases in levels of obesity around the world.[88] Thus, it is highly unlikely that mere recommendations of moderate leisure time physical activity – also extremely difficult to achieve and sustain- will suffice to prevent increasing burden of chronic diseases in the population and to restore the balance between activity and sedentarism, as proposed by some researchers.[20] Therefore, walking is the most accessible tool to achieve this goal.

Limitations

When evaluating the results of the results of this thesis, it should be taken into account certain limitations that appear in our studies.

Firstly, within the Changes in levels of PA (Article 1) one potential limitation of our study could be some degree of information bias because of different ways of administering the questionnaire: the baseline interview was face-to-face at the participant's home while the follow-up questionnaire was administered by telephone.[89] Face-to-face and telephone interviews have been shown to have high levels of agreement in a similar setting.[90] The questions used were the same, and interviewers were similarly trained. However, some degree of non-differential misclassification is possible and, hence, some bias towards the null hypothesis cannot be ruled out.

The results presented here attempt to show how a community has changed habits in the last decade. These correlates (sociodemographic, health conditions and lifestyles) should not be represented as unchanging factors, but factors with close interdependence, and also with changing patterns across time.

Unfortunately, our data do not allow us to adjust for changes in these factors, since we do not know exactly when the observed changes occurred. This is an aspect that future studies might consider addressing.

Finally, some potential limitations in the second study have to be considered. Participants selected for this analysis were adults over 45, thus the present findings cannot be generalized to younger ages, while levels of physical activity among younger people are even higher.[17,18] Although we used self-reports to assess physical activity, such information has been considered to be reliable and valid. [1, 61, 62] The present analysis controlled for major potential confounding variables, but residual confounding cannot be ruled out. All study variables were measured at baseline, and no repeated measures were considered in the design of the study. Hence, changes in the levels of physical activity and other variables might affect the results. A tendency to increase the levels of leisure time physical activity during the last decades in Spain has been described,[31] as well as other healthy life styles, whereas obesity and overweight have increased.[27] Given that almost all potential changes would have been favourable in terms of health gain; our results, if biased, would be an underestimation of the real impact of physical activity upon mortality.

Strengths

Among the strengths of the first study included in this thesis, its population-based, longitudinal and prospective design has permitted us to evaluate the actual change in physical activity patterns in a sample of the adult population. Moreover, we want to stress the high participation rates in the study. Ninety-two per cent of the Cornellà Health Interview Survey Follow-Up study members were effectively traced and the response rate at follow-up was 64.2%.[63] In addition, to our knowledge, this is the first study that evaluates changes and correlates in physical activity levels in a Mediterranean population-based cohort with active follow-up. The results presented here attempt to show how a community has changed habits in the last decade.

Although randomized controlled trials provide the strongest form of scientific evidence of physical activity intervention effectiveness, one of the most significant strengths of the observational cohort study offered in Article 2 is that it captures the variation of the community daily living. This study also includes a representation of

what happens in the general population, a limitation when studying samples recruited in randomized controlled trials or in selected population groups.[91]

Furthermore, to our knowledge, this investigation is the first one of its class in a Mediterranean population.

PART 6

Conclusions

6. Conclusions

The main conclusion of the thesis is that in these Mediterranean populations there were changes, in the last two decades, in the physical activity status in a positive way and, moreover, we identified that low and moderate levels of physical activity are associated to a reduction of all-cause mortality risk among both women and men and, furthermore, that there is a noticeable protective trend in women.

One of the key messages of this thesis is the contribution to the understanding of the activity-sedentarism research. Our study focused mainly on the ‘‘first step of change’’, from sedentary to light/ moderate LTPA. We identified the determinants of such changes that could improve the health status in those most in need of some increase of physical activity. On the other hand, the thesis shows that even small amounts of activity in diverse settings across the day, -for example, in walking, in transport, occupations, and house-work may decrease mortality.

From our point of view, as public health researchers, this thesis demonstrates that there is some degree of awareness in our population about the health benefits of performing movements.

Changes seem to be more constrained to gender traits. Demographic factors, such as age and sex, were related to physical activity changes. Gender differences in reported LTPA levels were consistent, and the association with age varied accordingly. Positive changes in LTPA were more likely in men than in women. Men reaching their 40s were more stable in their habits. Thus, targeting behavioural interventions to young men may have greater impact from a public health perspective.

Finally, this thesis adds epidemiological evidence to lead public health policy to adopt the “moderate physical activity” message in Mediterranean communities, but also, we contributed to the new paradigm what has become known as “active living” or “healthy lifestyle” approach. Although the epidemiological evidence at that point is not huge, it was proposed that energy expenditure in slight activities as walking or commuting or occupational could enhance

across the day to deliver health benefits. These results also contribute to the understanding of the epidemiology of the activity-sedentarism binomium. All aspects of daily life and their impacts on population health outcomes must be considered for a clear understanding of the new paradigm in activity-inactivity research.

Thus, new lines of research would be essential to updating and clarifying the evidence about the balance of activity–inactivity. New interventions and cohort studies should include patterns of sedentary behaviors, for example the health effect of sitting at work and in leisure time, as well as the benefits of active commuting or domestic activities.

Improvements in the way we assess daily energy expenditure and sitting time in population-based surveys could lead towards designing better public health interventions, aimed to drive population level changes in the prevalence of PA as an essential component in comprehensive health promotion programmes for the primary prevention of non-communicable diseases.

PART 7

Bibliography

Bibliography

[1] Haskell WL, Lee IM, Pate RP, *et al*. Physical activity and public health: updated recommendation for adults from the American College of Sport Medicine and the American Heart Association. *Circulation* 2007; **116**(9):1081–93.

[2] Physical activity and cardiovascular health. NIH Consensus Development Panel on Physical Activity and Cardiovascular Health. JAMA 1996; **276**(3):241–6.

[3] Leon AS, Connett J, Jacobs DR, Rauramaa R. Leisure-time physical activity levels and risk of coronary heart disease risk and death: the Multiple Risk Factor Intervention Trial. *JAMA* 1987; **258**(17):2388–95.

[4] Paffenbarger RS, Hyde RT, Wing AL, Hsieh CC. Physical activity, all-cause mortality, and longevity of college alumni. *N Engl J Med* 1986; **314**(10):605–13.

[5] Paffenbarger RS Jr, Hyde RT, Wing AL, *et al*. The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. *N Engl J Med* 1993; **328**(8):538–545.

[6] Paffenbarger RS, Kampert J, Lee IM, *et al*. Changes in physical activity and other lifeway patterns influencing longevity. *Med Sci Sports Exerc* 1994; **26**:857–65.

[7] Blair H, Kohl III, Barlow C, *et al*. Changes in physical fitness and all-cause mortality. A prospective study of healthy and unhealthy men. *JAMA* 1995; **273**:1093–8.

[8] Pavlou KN, Krey S, Steffee WP. Exercise as an adjunct to weight loss and maintenance in moderately obese subjects. *Am J Clin Nutr.* 1989; **49**:1115–23.

[9] Wendel-Vos G, Schuit A, Feskens E, *et al*. Physical activity and stroke. A meta-analysis of observational data. *Int J Epidemiol* 2004; **33**(4):787–8.

[10] Weyerer S. Physical inactivity and depression in the community. Evidence from the Upper Bavarian Field Study. *Int J Sports Med* 1992; **13**(6):492–6.

[11] Helmrich S, Ragland D, Leung R, Paffenbarger RS Jr. Physical activity and reduced occurrence of noninsulin-dependent diabetes mellitus. *N Engl J Med* 1991; **325**:147–52.

[12] Smith GD, Shipley M, Batty G, *et al*. Physical activity and cause-specific mortality in the Whitehall study. *Public Health* 2000; **114**:1–8.

[13] Department of Health and Human Services. 2008 physical activity guidelines for Americans. Washington DC: Department of Health and Human Services, 2008. http://www.health.gov/paguidelines/pdf/paguide.pdf (accessed 16th January 2014)

[14] U.S. Department of Health and Human Services. The Surgeon General's Vision for a Healthy and Fit Nation. Rockville (MD): Office of the Surgeon General, January 2010.

[15] US Department of Health and Human Services: Healthy People Understanding and Improving Health Volume I–II.2nd edition. Washington DC: US Department of Health and Human Services; 2010.

[16] United Nations. Prevention and control of non-communicable diseases.Report of the Secretary General.http://www.un.org/en/ga/president/65/issues/A-RES-65-238.pdf and http://www.un.org/ga/search/view_doc.asp?symbol=A/66/L.1 (accessed on 16 January 2013)

[17] Alwan A, MacLean DR, Riley LM, *et al*. Monitoring and surveillance of chronic non-communicable diseases: progress and capacity in high burden countries. *Lancet* 2010; **376**:1861–8.

[18] Jenkins CD. Principles of community health intervention. In: Jenkins CD, ed. Building better health. A handbook of behavioral change. Washington DC: PAHO, 2003.

[19] Brown WJ, Bauman AE, Owen N. Stand up, sit down, keep moving: turning circles in physical activity research? *Br J Sports Med* 2009; **43**:86–8.

[20] León-Muñoz LM, Martínez-Gómez D, Balboa-Castillo T, *et al*. Continued sedentariness, change in sitting time, and mortality in older adults. *Med Sci Sports Exerc* 2013; **45**(8):1501–7.

[21] Dominguez-Berjón MF, Borrell C, Nebot M, *et al*. Habitual physical activity in Barcelona, Spain. *Gac Sanit* 1998; **12**:110–7.

[22] Dominguez-Berjón MF, Borrell C, Nebot M, Plasència A. Leisure time physical activity and its association with sociodemographic variables and other health behaviours. *Gac Sanit* 1998; **12**:100–9.

[23] Generalitat de Catalunya; Departamento de Salut: Datos más destacados de la Encuesta de salud de Cataluña 2006.(Acceded 16 January2014)http://www10.gencat.cat/gencat/binaris/20070221_esca_cs_tcm34-53843.pdf

[24] Ministerio de Sanidad y Consumo. Encuesta Nacional de Salud de España. Madrid: Ministerio de Sanidad y Consumo; 1989.

[25] Ministerio de Sanidad y Consumo. Encuesta Nacional de Salud de España 1995. Madrid: Ministerio de Sanidad y Consumo; 1995.

[26] Ministerio de Sanidad y Consumo. Encuesta Nacional de Salud de España 1997. Madrid: Ministerio de Sanidad y Consumo; 1999.

[27] Rodriguez Artalejo F, Lopez Garcia E, Gutierrez-Fisac JL, *et al*. Changes in the prevalence of overweight and obesity and their risk factors in Spain, 1987–1997. *Prev Med* 2002; **34**(1):72–81.

[28] Navarro V, Benach J y la Comisión científica de estudios de las desigualdades sociales en salud en España. Desigualdades sociales en salud en España. Madrid: Ministerio de Sanidad y Consumo y The School of Hygiene and Public Health, The Johns Hopkins University; 1996. P 106–11.

[29] Borrell C, Domínguez-Berjón F, Pasarín MI, *et al*. Social inequalities in health related behaviours in Barcelona. *J Epidemiol Community Health* 2000; **54**:24–30.

[30] Ministerio de Sanidad y Consumo. Encuesta Nacional de Salud de España 2011. Madrid: Ministerio de Sanidad y consumo; 2012.(http://www.msssi.gob.es/estadEstudios/estadisticas/encuestaNacional/encuestaNac2011/NotaTecnica2011–12.pdf. Acceded 16th January 2014)

[31] Palacios-Ceña D, Alonso-Blanco C, Jiménez-Garcia R, *et al*. Time trends in leisure time physical activity and physical fitness in elderly people: 20 year follow-up of the Spanish population national health survey (1987-2006). *BMC Public Health* 2011; **11**:799.

[32] Lagerros YT, Lagiou P. Assessment of physical activity and energy expenditure in epidemiological research of chronic diseases. *Eur J Epidemiol* 2007; **22**(6):353–62

[33] Warren JM, Ekelund U, Besson H, *et al*. Assessment of physical activity - a review of methodologies with reference to epidemiological research: a report of the exercise physiology section of the European Association of Cardiovascular Prevention and Rehabilitation. *Eur J Cardiovasc Prev Rehabil* 2010; **17**(2):127–39.

[34] Oostdam N, van Mechelen W, van Poppel M. Validation and responsiveness of the AQuAA for measuring physical activity in overweight and obese pregnant women. *J Sci Med Sport* 2013; **16**(5):412–6.

[35] Bayer O, Jarczok M, Fischer J, *et al*. Validation and extension of a simple questionnaire to assess physical activity in pre-school children. *Public Health Nutr 2012*; **15**(9):1611–9.

[36] Ainsworth BE, Haskell WL, Leon AS, *et al*. Compendium of physical activities: energy cost of human movement. *Med Sci Sports Exerc* 1993; **25**(1):71–80.

[37] Ainsworth BE, Haskell WL, Leon AS, *et al*. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000; S498–S516.

[38] Ainsworth BE, Haskell WL, Herrmann SD, *et al*. 2011 Compendium of Physical Activities: a second update of codes and MET values. *Med Sci Sports Exerc* 2011; **43**(8):1575–81.

[39] O'Reilly GA, Spruijt-Metz D. Current mHealth Technologies for Physical Activity Assessment and Promotion. *Am J Prev Med* 2013; **45**(4):501–7.

[40] Task Force on Community Preventive Services, Recommendations to increase physical activity in communities. *Am J Prev Med* 2002; **22**(4S):67–72.

[41] U.S. Department of Health and Human Services Physical activity and health: a report of the Surgeon General, U.S. Atlanta: Department of Health and Human Services, Centres for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion; 1996.

[42] U.S Department of Health and Human Services. Healthy people 2010: conference edition. Washington, DC: Department of Health and Human Services; 2000.

[43] Physical Activity Guidelines for Americans Midcourse Report: Strategies to Increase Physical Activity Among Youth. Washington, DC: U.S. Department of Health and Human Services, 2012.

[44] Pate R, Pratt M, Blair S, *et al*. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* 1995; **273**:402–7.

[45] Kahn E, Ramsey L, Brownson R, *et al*. The effectiveness of interventions to increase physical activity. *Am J Prev Med* 2002; **22**(4S):72–107.

[46] Galan I, Rodriguez-Artalejo F, Tobías A, *et al*. Clustering of behavioural risk factors and their association with subjective health. *Gac Sanit* 2005; **19**:370–80.

[47] Rydin Y, Bleahu A, Davies M, *et al*. Shaping cities for health: complexity and the planning of urban environments in the 21st century. *Lancet* 2012; **379**(9831):2079–108.

[48] Pratt M, Epping JN, Dietz W. Putting physical activity into public health: A historical perspective from the CDC. *Prev Med* 2009; **49**:301–2.

[49] Hallal PC, Azevedo MR, Reichert FF, Siqueira FV, Araújo CL, Victora CG. Who, when, and how much? Epidemiology of walking in a middle-income country. *Am J Prev Med*. 2005; **28**:156–61.

[50] Pekkanan J, Marti B, Nisinen A, Toumilehto J. Reduction of premature mortality by high physical activity: a 20-year follow-up of middle-aged Finnish men. *Lancet* 1987; **1**:1473–7.

[51] Johansson SE, Sundquist J. Change in lifestyle factors and their influence on health status an all-cause mortality. *Int J Epidemiol* 1999; **28**(6):1073–80.

[52] Nusselder WJ, Franco OH, Peeters A, Mackenbach JP. Living healthier for longer: Comparative effects of three heart-healthy behaviors on life expectancy with and without cardiovascular disease. *BMC Public Health* 2009; **9**:487.

[53] Holmes MD, Chen WY, Hankinson SE, Willett WC. Physical activity's impact on the association of fat and fiber intake with survival after breast cancer. *Am J Epidemiol* 2009; **170**(10):1250–6.

[54] Patel AV, Bernstein L, Deka A, *et al*. Leisure time spent sitting in relation to total mortality in a prospective cohort of US adults. *Am J Epidemiol* 2010; **172**(4):419–29.

[55] Smith GD, Shipley M, Batty G, *et al*. Physical activity and cause-specific mortality in the Whitehall study. *Public Health* 2000; **114**:1–8.

[56] Myers J, Kaykha A, George S, *et al*. Fitness versus physical activity patterns in predicting mortality in men. *Am J Med* 2004; **117**(12):912–8.

[57] Byberg L, Melhus H, Gedeborg R, *et al*. Total mortality after changes in leisure time physical activity in 50 year old men: 35 year follow-up of population based cohort. *BMJ* 2009; **338**:b688.

[58] Stamatakis E, Hamer M, Lawlor DA. Physical Activity, Mortality, and Cardiovascular Disease: Is Domestic Physical Activity Beneficial?: The Scottish Health Survey–1995, 1998, and 2003. *Am J Epidemiol* 2009; **169**(10):1191–1200.

[59] Baer HJ, Glynn RJ, Hu FB, *et al*. Risk factors for mortality in the nurses' health study: a competing risks analysis. *Am J Epidemiol* 2011; **173**:31.

[60] Kvaavik E, Batty GD, Ursin G, *et al*. Influence of individual and combined health behaviors on total and cause-specific mortality in men and women: the United Kingdom health and lifestyle survey. *Arch Intern Med* 2010; **170**:711–8.

[61] van Dam RM, Li T, Spiegelman D, *et al*. Combined impact of lifestyle factors on mortality: prospective cohort study in US women. *BMJ* 2008; **337**:a1440.

[62] Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: systematic review and meta-analysis of cohort studies. *Int J Epidemiol* 2011; **40**(5):1382–400.

[63] Garcia M, Schiaffino A, Fernández E, *et al*. The Cornellà Health Interview Survey Follow-up (CHIS.FU) Study:design,methods,and responserate. *BCM Public Health* 2003; **3**:12.

[64] Garcia M, Fernandez E, Schiaffino A,*et al.* Smoking reduction in a population-based-cohort. *Prev Med* 2005; **40**:679–84.

[65] Garcia M, Fernandez E, Schiaffino A, *et al*. Attrition in a population-based cohort eight years after baseline interview: The Cornell

Health Interview Survey Follow-up (CHIS.FU) Study. *Ann Epidemiol* 2005;**15**:98–104.

[66] Borrell C, Baranda L, Rodriguez M. Manual de l'enquesta de salut de Barcelona 2000. Barcelona: Institut Municipal de Salut Pública, 2002.

[67] Borrell C, Muntaner C, Solà J, *et al*. Immigration and self-reported health status by social class and gender: the importance of material deprivation, work organisation and household labour. *J Epidemiol Community Health* 2008; **62**(5):e7.

[68] Gutierrez-Fisac JL, Regidor E, Lopez Garcia E, *et al*. The obesity epidemic and related factors: the case of Spain. *Cad Saude Publica* 2003; **19**(S1):S101–S110.

[69] Weinsier R, Hunter G, Heini A, *et al*. The etiology of obesity: relative contribution of metabolic factors, diet and physical activity. *Am J Med* 1998; **105**:145–50.

[70] Pols M, Peeter P, Twisk J, *et al*. Physical activity and cardiovascular disease profile in women. *Am J Epidemiol* 1997; **146**:322–8.

[71] Guallar-Castillon P, Santa Olalla Peralta P, Banegas JR, *et al*. Actividad física y calidad de vida de la población adulta mayor en España. *Med Clin (Barc)* 2004; **123**:606–10.

[72] Rainwater DL, Mitchell BD, Comuzzie AG, *et al*. Association among 5-year in weight, physical activity, and cardiovascular disease risk factors in Mexican Americans. *Am J Epidemiol* 2000; **152**:974–82.

[73] Sternfeld B, Sidney S, Jacobs D Jr, *et al*. Seven-year changes in physical fitness, physical activity, and lipid profile in the CARDIA Study. *Ann Epidemiol* 1999; **9**:25–33.

[74] Schroder H, Elosua R, Marrugat J, *et al*. The relationship of physical activity with dietary cancer-protective nutrients and cancer-related biological and life style factors. *Eur J Cancer Prev* 2003; **12**:339–46.

[75] Merritt RK, Caspersen C. Trend in physical activity patterns in young adults: the behaviors risk factor surveillance system, 1986–1990. *Med Sci Sports Exerc* 1992; **24**:526–30.

[76] Hill J, Melanson E. Overview of the determinants of overweight and obesity: current evidence and research issues. *Med Sci Sports Exerc* 1999; **31**(11S):S515–21.

[77] Jebb SA, Moore MS. Contribution of a sedentary lifestyle and inactivity to the etiology of overweight and obesity: current evidence and research issues. *Med Sci Sports Exerc* 1999; **31**(11S):S534–41.

[78] Ford ES, Merritt RK, Heath GW, *et al*. Physical activity behaviours in lower and higher socio-economic status populations. *Am J Epidemiol* 1991; **133**:1246–56.

[79] Schroder H, Rohlfs I, Schmelz EM, *et al*. Relationship of socioeconomic status with cardiovascular risk factors and lifestyle in a Mediterranean population. *Eur J Nutr* 2004; **43**:77–8.

[80] Droomers M, Schrijvers CT, Mackenbach JP. Educational level and decreases in leisure time physical activity: predictors from the longitudinal GLOBE study. *J Epidemiol Community Health* 2001; **55**:562–8.

[81] Schmitz K, French S, Jeffery R. Correlates of changes in leisure time physical activity over 2 years: The Healthy Worker Project. *Prev Med* 1997; **26**:570–9.

[82] Hill JO, Peters JC. Environmental contributions to the obesity epidemic. *Science* 1998; **280**:1371–4.

[83] Wimbush E, MacGregor A, Fraser E. Impacts of a national mass media camping on walking in Scotland. *Health Prom Int* 1998; **13**:45–54.

[84] World Health Organization. Ageing and life course. The global embrace 2000. Highlights from Europe. Geneva: WHO, 2000 Available at: www.who.int/docstore/globalmovement/embrace2000

[accessed 30 May, 2006].

[85] Macera CA, Ham SA, Yore MM, *et al*. Prevalence of physical activity in the United States: Behavioral Risk Factor Surveillance System, 2001. *Prev Chronic Dis* 2005; **2**(2):1–10.

[86] Sundquist K, Qvist J, Sundquist J, Johansson SE. Frequent and Occasional Physical Activity in the Elderly: A 12-Year Follow-up Study of Mortality. *Am J Prev Med* 2004; **27**: 22–7.

[87] Lindsted KD, Tonstad S, Kuzma JW. Self-report of physical activity and patterns of mortality in Seventh-Day Adventist men. *J Clin Epidemiol* 1991; **44**:355-64.

[88] Leon DA. Editorial: trends in European Life expectancy: a salutary view. *Int J Epidemiol* 2011; **40**(2):271–7.

[89] Garcia M, Fernández E, Schiaffino A, *et al*. Survey Follow-up Study Group. Phone tracking in a follow-up study. *Soz Praventivmed* 2005; **50**:63–6.

[90] Galan I, Rodriguez-Artalejo F, Zorrilla B. Comparación entre encuestas telefónicas y encuestas ‘‘cara a cara’’ domiciliarias en la estimación de hábitos de salud y prácticas preventivas. *Gac Sanit* 2004; **18**:440–50.

[91] de Groot LC, Verheijden MW, de Henauw S, *et al*. Lifestyle, nutritional status, health, and mortality in elderly people across Europe: a review of the longitudinal results of the SENECA study. *J Gerontol A Biol Sci Med Sci* 2004; **59**(12):1277–84.