Obesity in Older Adults: Epidemiology and Implications for Disability and Disease

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Summary

Obesity is a worldwide problem with increasing prevalence and incidence in both developed and developing countries. In older adults, excess weight is associated with a higher prevalence of cardiovascular disease, metabolic disease, several important cancers, and numerous other medical conditions. Obesity has been also associated with increased functional limitations, disability, and poorer quality of life. Additionally, obesity has been independently associated with all-cause mortality. The obesity epidemic has important social and economic implications, representing an important source of increased public health care costs. The aim of this review is to report the epidemiology of obesity world-wide and the implications of obesity on disability and chronic diseases.

Keywords

Obesity; Older Adults; Disability; Chronic Disease

Obesity is a health concern in both developed and developing countries. Numerous studies have documented an increase in the prevalence of obesity worldwide, a trend that has been described as an "epidemic". Increases in the prevalence of obesity have been observed in men and women, in all age groups, in all major ethnic groups, and at all educational levels. According to the World Health Organization (WHO), obesity prevalence has doubled since 1980 [1]. Some authors argue that up to one third of the life expectancy gains over time attributable to public health achievements, such as reductions in smoking are counteracted by the simultaneous increase in obesity prevalence [2;3]. Among older adults, obesity has been related to higher rates of disability and poor overall health [4]. This is especially relevant given the expected worldwide growth of older adult populations.

We searched Medline, PubMed, EMBASE and World of Science databases and websites for the World Health Organization, and for major longitudinal studies on ageing such as the English Longitudinal Study on Ageing (ELSA) [http://www.esds.ac.uk/longitudinal/access/elsa/] the Survey of Health, Ageing and Retirement in Europe (SHARE) [http://www.share-project.org/], the Health and Retirement Study (HRS) [http://hrsonline.isr.umich.edu/], **The Health, Well-Being, and Ageing Survey (SABE)**. We did not limit the search by type of study given the complexity of the

topics addressed; however, we did limit the search to manuscripts published in core clinical and epidemiological journals between 1991 and 2011, given the focus of the review. Our initial search terms included 'obesity', 'prevalence', 'trends', 'older adults' and 'epidemiology'. We went on to conduct several further searches to find articles related to obesity and disability and obesity and chronic diseases for each of the sub-sections covered in this article.

Epidemiology of Obesity around the World

Comparisons between regions around the world indicate a wide variation in prevalence of obesity. Despite these regional differences, over time the prevalence of obesity has increased worldwide [1]. Table 1 summarizes the prevalence of obesity according to studies published in the last two decades using information from three regions in the world: North America (USA and Canada), Latin America and Europe.

In the United States, studies using data from the National Health and Nutrition Examination Survey (NHANES) report increasing trends in obesity over time [5-10]. Ford and colleagues reported an increase in the prevalence of obesity from 11.1% in the 1970's to 19.3% in the early 2000's [9]. The most recent data from NHANES report obesity prevalence to be approximately 32% for men and 36% for women [8;10]. The difference between men and women is not statistically significant based on the overlapping confidence intervals. Nevertheless, the trend over time has continued to increase for men, while for women it seems to be stabilizing [8;11]. Race /ethnic differences are also reported in the increasing obesity trends, with African-Americans having the highest rates, followed by Hispanics [8].

Obesity in Canada is lower. The overall prevalence of obesity in the mid 1990's was reported at 12.8% [12], half that reported in the USA using data from the NHANES study in a similar time period (Table 1). A steady rise in the obesity trends is observed in Canada as well, with obesity rates of 8.1% for men in the 1970's increasing to 13.4% in the 1990's and rates of 12.7% rising to 15.4% in women [13]. MacDonald and colleagues, using the cut-off point of 27 kg/m^2 for obesity, found obesity rate of 35% for men 27% for women in ten provinces from Canada [14]. The lower cut-off point explains the large difference in the prevalence between this and the other Canadian studies (Table 1). Nevertheless, we cannot determine why the prevalence rate is higher in men than in women, in contrast to studies in North America. Ethnic differences are also observed in Canada, with Aboriginals reporting higher rates of obesity [15;16].

The few studies available on prevalence of obesity in Latin America and the Caribbean in older adults also report an increase over time. A large variation between countries is also observed [17-19]. Using data from the Health, Well-being and Ageing Survey (SABE), the prevalence of category I obesity (BMI of 30 to < 35 Kg/m^2) for men and women combined, ranged between 10.4% in Havana to 22.9% in Santiago; the prevalence of category II and extreme obesity (BMI = 35 Kg/m^2) ranged from 2.9% in Havana to 15.7% in Montevideo [17]. Thus, obesity of any category ranged between 13.3% and 38.6% in the SABE study (Table 1). The two remaining studies summarized in Table 1 on Latin America, were conducted only in Brazil and Mexico. In Brazil the prevalence of obesity seemed to reach a plateau in the early 2000's for women,while for men the trend continued to increase [18]. The prevalence reported in the single country studies falls in the range reported in the SABE study (Table 1).

In Europe, both cross-sectional and longitudinal studies report a large variation in the prevalence of obesity between countries. Using data from the Europe Action on Secondary and Primary Intervention through Intervention to Reduce Events (EUROASPIRE) surveys, the average prevalence of obesity increased from 25% in EUROASPIRE I to 38% in

EUROASPIRE III [20]. Studies using data from the Survey of Health, Ageing and Retirement in Europe (SHARE) and the English Longitudinal Study of Ageing (ELSA) reported average prevalence of obesity for men of 16.2% and 17.8% for women [21]. Nevertheless the variation observed ranges between 12.8% for men in Sweden to 20.2% for men in Spain, and between 12.3% for women in Switzerland to 21.9% for women in Greece (Table 1). Studies using data from only one country also reported a difference in the prevalence of obesity between men and women and an increasing trend in the prevalence of obesity over time [22-27]. In most countries the prevalence of obesity is higher for women (Table 1).

Cross-sectional studies comparing USA to Europe showed that obesity rates in USA were higher for both men and women(Table 1). In 2004, the prevalence of obesity for the USA was reported at 30.7% for men compared to 17.6% in Europe, and 37.9% in women compared to 24.2% respectively [28]. A large variability is noted again between obesity rates in the different European countries. However, no country reaches the exceedingly high obesity rates of the USA. One last study examined obesity rates among Inuit people in Canada, Alaska and Greenland and reported no significant differences between countries, with an overall prevalence of obesity of 15.8% for Inuit men and 25.5% for Inuit women [29].

Finally, Stewart and colleagues used data from the NHANES to predict obesity rates in 2020 and estimate its impact on mortality [3]. Their projections showed that life expectancy is decreased by almost 1 year in the USA for a representative 18 year-old person, assuming trends in smoking continue to decrease and trends in body mass index (BMI) continue to increase at the same rate observed between 1973 and 2005. Additionally, the projection shows that the overall prevalence of obesity for adults in the USA will be 45% by the year 2020 [3].

We did not include Asia or Australia as regions in Table 1 because of the limited number of studies available on the epidemiology of obesity in older adults in these continents. Additionally, a large variability in the prevalence of obesity has been reported in the literature on Asian older adults. However, to include all major regions in the world we analyzed two documents that analyze obesity in Asia and Australia. Based on a report by the WHO, the major difficulty with accurately examining obesity among Asians is the large variation in cultural and economic conditions of Asian populations and the fact that current WHO cut-off points for obesity seem to provide an erroneous estimate based on higher prevalence of adverse events at lower BMI values. This report by the WHO proposes that the cut-off point for obesity among Asian adults should be 25 kg/m^2 [30].

The WHO report on Asia summarizes some studies that have looked at epidemiology of obesity. Most data on obesity in Asia come from single country studies or from countries where a large portion of the population is of Asian origin, like the island of Mauritius. Obesity trends are rapidly rising in all Asian nations. Obesity rates range between less than 1% in rural populations in countries like China, to around 9% in urban areas of Malaysia. A large variation by gender and ethnicity is observed in several countries including Malaysia and China. In summary, the data from Asian countries reports much lower obesity rates compared to other regions. The WHO however, strongly advocates for a new definition of obesity with different cut-off points based on the trends in obesity rates and the increase in the prevalence of obesity associated complications such as cardiovascular diseases.

In Australia, analysis of trends from cross-sectional surveys conducted since the 1980's were summarized by the Australian Institute of Health and Welfare in a bulletin published in 2004 [31]. Similar to what has been reported in other continents, the rates of obesity among older adults has increased over time. Between the 1980's and the early 2000's an increase in

prevalence of obesity was observed from 11% to 23% in adults over 65 [31]. The most recent reports show that between 25-30% of adults approaching retirement in Australia are obese.

In summary, obesity has increased noticeably in all continents among older adults. Large variations between countries, race/ethnic groups and genders are observed. Despite these variations, public health implications need to be carefully analyzed and addressed to prevent disability and decreased quality of life for older adults around the world in the near future.

Obesity and Disability

Disability is a broad term that can be defined in many different ways. Lack of a single definition and availability of several validated tools to measure different types of disability make cross-study comparisons on disability difficult. Nevertheless, the ample literature showing that disability increases the risk of mortality and institutionalization and affects quality of life in older age make disability a concept that must be carefully analyzed and better understood [32-35]. Conditions that increase the risk of disability are therefore highly important.

Table 2 summarizes relevant studies that analyze the relationship between obesity and disability. Obesity is not measured consistently although all studies use either BMI, waist circumference or body composition to define obesity. Similarly, the definition of disability varies between the different studies. The first studies listed are longitudinal studies. They are consistent in showing that, over time, the presence of obesity increases the risk of becoming disabled [25;36-43]. Nevertheless, of the nine longitudinal studies listed, seven studies use Activities of Daily Living (ADL) to define disability [25;36;38;39;41-43]. Five of the seven studies use the same six activities (walking across a room, bathing, eating, dressing, toileting and transferring in and out of bed) and define disability as difficulty performing one or more activities [25;36;38;39;43]. From these studies we can conclude that obesity is an independent risk factor for developing ADL disability over time. The remaining studies use upper and lower body function and work related disability. Each study concludes that obesity increases the risk of the defined disability [37;40]. The studies by Reynolds et al. and Walter et al. also conclude that obesity hampers the probability of recovery from disability in older adults [38;41]. In some of the longitudinal studies, the effect of obesity on disability was larger for women compared to men (Table 2).

Following the longitudinal studies, cross-sectional studies analyzing the relationship between obesity and disability are listed (Table 2). Similar to the longitudinal studies, disability is defined in different ways. Of the 11 cross-sectional studies included, seven use ADL exclusively or in combination with other functionality measures to define disability [44-50]. Three studies also use Instrumental Activities of Daily Living (IADL) to define disability [46;48;50]. The remaining studies use either physical function or mobility disability to define disability [51-54]. All studies conclude that obesity is related to increased disability regardless of how it is measured. Some of the studies analyze the relationship between obesity and muscle strength and suggest that, despite the deleterious effects of obesity on muscle function, additional pathways need to be analyzed to understand the pathophysiology behind the onset of disability in older obese adults [50-54].

Several studies report that the relationship between weight or BMI and disability has a "U" or a "J" shape, meaning that not only obesity but underweight older adults have increased risk of disability [36;45;48]. Normal weight and maybe some overweight older adults seem to have the lowest risk of disability of all weight or BMI groups. This has important implications for prevention and treatment schemes, since losing too much weight can be detrimental for older adults as well.

In summary, obesity is related to increased risk of disability among older adult populations. Obesity also seems to affect recovery from disability over time. Obesity not only affects functional status but it also affects mobility. Policy makers and healthcare providers need to keep this relationship in mind, and design obesity prevention and obesity management programmes that can improve functional status in older adults and protect them from becoming disabled, with resultant poor quality of life.

Implications of obesity on chronic diseases

Despite the widely know deleterious effects of obesity on overall health, obesity in older age has to be analyzed with caution. Obesity significantly increases the risk of death among older adults. Never the less, the relationship between BMI and mortality is unique in the older adult population because very low BMI values are related to the highest mortality risk, this risk decreases as BMI increases to normal and overweight values and then mortality risk increases again, with a sharp increase in BMI values greater than $35kg/m^2$ [36;55;56]. Additionally, weight loss has been reported as a risk factor for adverse events in some older adults including fractures, falls and mortality [57;58]. Despite this, healthcare costs for older obese adults are higher than for older adults with normal weight[59;60]. Similarly, disability rates and complications from obesity have been widely reported among the older adult population [61-63]. We reviewed the literature and have summarized the implications of obesity on different diseases in the older adult population.

Obesity and Cardiovascular disease

Obesity is an independent risk factor for development of heart failure, acute events like myocardial infarctions and stroke in older adults [64;65]. Obesity increases the risk of hypertension and affects overall response to anti-hypertensive medications [66-68]. A "U" shaped relationship between BMI and hypertension has been reported [69]. Two major causes have emerged as explanatory causes for cardiovascular disease resulting from obesity: anatomic and physiologic alterations. Anatomic alterations are explained because obesity affects the architecture and physiology of the cardiovascular system. Obesity causes atrial and ventricular enlargement and plaque formation in the vessels [70-72]. These changes not only affect cardiovascular function, but also increase the risk of developing potentially lethal conditions like atrial fibrillation and abdominal aortic aneurysms [73;74].

Obesity triggers metabolic dysregulation and inflammation [50;75;76]. Decreased levels of natriuretic peptide, a peptide that protects against acute events like myocardial infarctions, have been reported [68;77]. Other physiologic alterations include increased levels of inflammatory markers (interleukin-6, C - reactive protein and tumor necrosis factor) that affect the body's response to physiologic changes and put an additional burden on the cardiovascular system [76]. Increased adiposity enhances insulin resistance and therefore the risk for adverse cardiovascular events overall [50;78].

Obesity, Diabetes and the Metabolic Syndrome

Obesity, diabetes and the metabolic syndrome are closely related. Obesity and diabetes are distinct clinical conditions that occur independently despite sharing some pathophysiologic pathways. The metabolic syndrome is also independent from obesity and diabetes. It is a collection of risk factors that cause damage to the cardiovascular system, increasing the risk of heart attack, stroke and other cardiovascular diseases. Increased body fat and increased blood sugar are two of the eight components of the metabolic syndrome[79;80].

Unlike the relationship between obesity and mortality in older adults, the relationship between obesity, diabetes and the metabolic syndrome is very similar in older adults compared to younger adults. A large body of evidence has shown that obesity increases the

risk of developing diabetes and the metabolic syndrome [80;81]. There is also evidence that obesity, diabetes and the metabolic syndrome are independent risk factors for cardiovascular disease [80]. Increased oxidative stress in fatty tissue of obese individuals has been proposed as a pathogenic mechanism leading to the metabolic syndrome [82]. Additionally, severity of obesity (determined by National Heart Lung and Blood Institute Task Force categories: class 1, class 2 and class 3) is associated with an increasing trend in risk of development of diabetes and the metabolic syndrome [83]. It has been reported that this relationship between obesity, diabetes and the metabolic syndrome is especially important among minority populations in developed countries given the higher rates of obesity compared to other population groups and the higher rates of complications and mortality [79].

Obesity and Cancer

More than 60% of cancers occur over the age of 65 [84]. In the last decade, findings in cancer epidemiology have highlighted the importance of the relation between obesity and cancer [85]. Increased body mass and adiposity have been established as risk factors for the development of cancers that affect a large portion of the older adult population such as colon cancer, breast cancer, and prostate cancer [85]. Three hormonal systems have been proposed as causal pathways : insulin and insulin-like growth factor axis, sex steroids and adipokines [85;86]. These hormonal systems are altered in obesity; however, their role in the development of cancer is probably different for each cancer site. Additionally, the link between obesity and cancer seem to be different for men and women [85-87].

To date there have been no clinical trials exploring the effect of losing weight, or even maintaining weight, on cancer incidence [85;86]. However, there is evidence from observational studies that weight maintenance and controlled weight loss may decrease the risk of developing some types of cancers [88;89]. Despite the limited information, it has been shown that obesity increases the risk of delayed cancer diagnosis, complications during cancer treatment and poor outcomes after treatment [90;91].

Obesity and arthritis

A common limitation when addressing arthritis in older adults is the lack of differentiation between the types of arthritis described. The most common types of arthritis affecting older adults are osteoarthritis, rheumatoid arthritis and gout. The pathophysiology, treatment and course of each type of arthritis are very different. However, the negative effect of arthritis on older adults is mostly due to its effect on overall physical and mental health and disability rather than a direct increase in mortality risk [92].

The relationship between obesity and arthritis has not been completely explained. Despite the differences in the most common types of arthritis in older adults, both obesity and arthritis are pro-inflammatory conditions that increases the concentration of cytokines and adipokines as previously reported [93]. Additionally, arthritis impairs physical activity, necessary for weight loss, and a cornerstone for self-management of arthritis because it diminishes pain and improves physical function [92;94]. Both increased levels of inflammatory markers and decreased physical activity in relation to obesity impede adequate management of arthritis and increase the long term effects of the disease [95]. In addition, obesity accelerates the deterioration of joint function in older adults with arthritis and negatively affects some outcomes from surgical interventions [92;95].

Obesity and some Geriatric syndromes

Obesity has been linked to some geriatric syndromes. The pro-inflammatory state caused by obesity has been linked to age related muscle loss or sarcopenia [4;50]. Sarcopenia has been shown to increase disability and overall mortality and may explain some of the

complications reported in obese older adults [4]. Sarcopenia and obesity are independent conditions with separate pathophysiologic pathways. However, older adults with comorbid sarcopenia and obesity have become the centre of several studies. Co-occurrence of sarcopenia and obesity places older adults in a unique state of disease that increases the risk of adverse events and requires special interventions [4;50;52;54]. Additionally, the pro-inflammatory state has also been related to vascular dysfunction in the brain that increases the production of beta-amyloid, a key component of senile plaques that accumulate in the brain in Alzheimer's disease [96-98].

In summary, the pro-inflammatory state caused by obesity, in addition to the limitations in physical function, are common links to the added burden of disease when obesity is present concomitantly with many chronic conditions in older adults. Additionally, obesity is a marker of poor outcomes for most interventions for chronic conditions and interferes with management of most chronic diseases in older adults.

Conclusions

Obesity among older adults has increased noticeably in the last two decades in all continents. However, large variations between countries, race/ethnic groups and genders are observed. Obesity is related to increased risk of disability among older adult populations regardless of the measures used. Obesity affects functional status and mobility. Inflammation caused by obesity is linked to the added burden of disease when obesity is present concomitantly with many chronic conditions in older adults. Additionally, it is a marker of poor outcomes for most interventions for chronic conditions and interferes with management of most chronic diseases in older adults.

Policy makers and healthcare providers need to keep obesity-related health outcomes in mind and design obesity prevention and management programmes that can improve functional status in older adults and protect them from becoming disabled with resultant poor quality of life.

Acknowledgments

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Table 1

Summary of literature review of studies reporting prevalence of obesity around the world in the past two decades.

Author	Year	Age Inclusion	Type of Study	BMI cut-off points	Mean BMI or prevalence	Region	Notes
MacDonald, SM[14]	1997	18 - 74 y/o	Cross sectional surveys conducted in ten Canadian provinces between 1986 - 1992	Obesity considered as BMI ≥ 27	Mean BMI for men was 25.8 (SD 4.03) and 24.9 (SD 5.14) for women. A total of 35% of men and 27% of women were considered to be obese.	North America	Additional study conducted with same dataset by the same group reported no differences in BMI between urban and rural areas of Canada
Torrance, GM[13]	2002	20 - 69 y/o	Cross sectional study using three different national surveys to determine trend in obesity of adults in Canada.	WHO cut-points	Prevalence of obesity increased over time for men from 8.1% (1970-72) to 12% (1978-79) to 13.4 (1986-1992). Similarly for women the prevalence increased from 12.7% (1970-72) to 14.9% (1978-79) to 15.4 (1986-1992).	North America	No differences observed by education, however smoking status had a strong relationship with increasing obesity trends.
Kaplan, MS[12]	2003	≥ 65 y/o	Cross sectional study using wave 2 (1996-1997) of the CNPHS survey	WHO cut-points	A total of 12.8% of older adults fell under the obese category	North America	Overall, men were 37% more likely to be obese than women. Obesity was also more common among younger senior adults; less educated; unmarried; nonsmokers; infrequent and heavier alcohol users; physically inactive; more comorbidities; functional limitations; poorer self-rated health; and reporting psychological distress. Place of birth also predicted obesity.
Crimmins, E[7]	2005	≥ 65 y/o	Longitudinal	WHO cut-points	Prevalence increased from 21.4% (1988-1994) to 30.8% (1999-2000)	North America	NHANES III and IV data
Ford, ES[9]	2009	25 to 74 y/o	Cross-sectional	WHO cut-points	Age adjusted prevalence of obesity: 11.1[1971-1975]; 10.9 [1976-1980]; 15.5 [1988-1994]; 19.3 [1999-2004]	North America	NHANES
Bleich, SN[5]	2009	≥ 20 y/o	Cross sectional	WHO cut-points	Prevalence of obesity reported at 22% [1988-1994] and 31% [1999-2004]	North America	NHANES. Examines relationship between increased consumption of sugar-sweetened beverages with increasing prevalence of obesity
Lix, LM[16]	2009	≥ 20 y/o	Cross sectional study using 2 waves of the CCHS (2000-2001 and 2005-2006)	WHO cut-points	At baseline 20% of the population was obese. Between baseline and follow up there was an increase in prevalence of obesity but only for Aboriginal participants. Prevalence of obesity at baseline for Aboriginals was 20.2% (95% CI 18.1-22.4) and 18.5% (95% CI	North America	Cover three regions of northern Canada. Variations in prevalence of obesity observed by ethnic group and region.

Author	Year	Age Inclusion	Type of Study	BMI cut-off points	Mean BMI or prevalence	Region	Notes
Cohen, JD[6]	2010	20 to 74 y/o	Analysis of trend using data from NHANES I, II and III	WHO cut-points	15.9-21.0) for Non-Aboriginals. At follow-up the prevalence was 25.4 %(95% CI 20.5-30.2) and 21.1 %(18.3-23.9) for Aboriginals and Non-Aboriginals respectively.	North America	NHANES 1976-2006 data. Examined trends in serum lipids as main outcome. Only individuals with 1 or more total cholesterol or lipid results were included.
Flegal, KM[8]	2010	≥ 20 y/o	Analysis of trends using cross-sectional data from NHANES between 1999-2000 and 2007-2008	WHO cut-points	Mean BMI for each cross-section: 25.5(±5.0) [1976-1980]; 27.3(±5.9) [1988-1994]; 28.7(±6.6) [1999-2006]. Prevalence of obesity for each cross-section: 15%[1976-1980], 26% [1988-1994] and 34% [1999-2006].	North America	Differences observed by gender and race/ethnicity. Between 1999-2000 and 2007-2008 a 4.7% increase in obesity for men and 2.1% increase for women were observed. Prevalence change for women was not significant. Prevalence of overweight and obesity was 68%.
Stenholm, S[11]	2010	≥ 60 y/o	Longitudinal study in Baltimore	WHO cut-points	In 2007-2008 the age adjusted prevalence of obesity was 33.8% (95% CI 31.6%-63.0%). For men it was 32.2% (95% CI 29.5-35.0) and for women 35.5% (95% CI 33.2-37.7).	North America	Secular increase in bodyweight in three cohorts of older white men in the US independent of body height. BLSA study
Ford, ES[10]	2011	≥ 20 y/o	Analysis of trends using cross-sectional data between 1999-2000 and 2007-2008	WHO cut-points	Mean BMI for men of three different cohorts from the BLSA study: 24.2(±3) [1877-1899]; 25.2(±3.2) [1900-1919]; 27.5(±4.3) [1920-1943]	North America	Analyzes trends in obesity and abdominal obesity using NHANES data
Bruce, SG[15]	2010	≥ 18 y/o	Cross Sectional study using data from an Aboriginal group in Canada	WHO cut-points	Age adjust mean BMI for men 26.9 in 1999-2000 and 32% in 2007-2008; In women 33.2% in 1999-2000 and 35.2 in 2007-2008	North America	Analyses one group of Aboriginal. Aboriginals in Canada are considered to have poorer overall health compared to other ethnic groups in Canada.
Ruiz-Arregui, L[19]	2005	≥ 60 y/o	Cross sectional study using the first wave (2001) of the MHAS	WHO cut-points	A total of 56% of the sample were obese. A total of 50% of men and 65% of women were obese.	Latin America	Hypertension and limitations in walking were associated to higher prevalence of obesity
Monteiro, CA[18]	2007	≥ 20 y/o	Uses cross sectional data from 3 national surveys in Brazil (1975, 1989, 2003) to estimate trends in Obesity	WHO cut-points	Obesity was present in 20.9% of the total population. A total of 24.8% of women and 17.3% of men were obese.	Latin America	Obesity trends in men increased but in women remained the same between 1989 and 2003 compared to 1975-1989. Increases in obesity were more prevalent in lower SES quintiles for both men and women.

Additional prevalence data (Monteiro row): Mean BMI Men: 22.4 SE 0.08 [1975], 23.5 SE 0.07 [1989], 24.6 SE 0.04 [2003]. Mean BMI Women: 23.0 SE 0.08 [1975], 24.5 SE 0.07 [1989], 24.7 SE 0.04 [2003]. Prevalence of obesity was 2.7% in 1975, 5.1%

Author	Year	Age Inclusion	Type of Study	BMI cut-off points	Mean BMI or prevalence	Region	Notes
Al Snih, S[44]	2010	≥ 65 y/o	Cross sectional study using data from the SABE study that included 6 cities in Latin America and the Caribbean	WHO cut-points, separates category I (BMI between 30 and 34.9) from category II and extreme obesity (BMI ≥ 35)	in 1989 and 8.8% in 2003 for men and 7.4%, 12.4% and 13% for women in the same years. Mean BMI for the different cities: Bridgetown, Barbados 26.9 (95% CI 26.4-27.3); Sao Paolo, Brazil 26.4 (95% CI 26.1-26.7); Santiago, Chile 27.7 (95% CI 27.2-28.2); Havana, Cuba 24.2 (95% CI 23.9-24.5); Mexico City, Mexico 27.5 (95% CI 27.1-27.8); Montevideo, Uruguay 28.3 (95% CI 27.9, 28.8). The prevalence of category I obesity was: Bridgetown, Barbados 15.2% (95% CI 13.1-17.4); Sao Paolo, Brazil 17.6 (95% CI 15.5-19.8); Santiago, Chile 22.9% (95% CI 20.1-25.8); Havana, Cuba 10.4% (95% CI 8.4-12.4); Mexico City, Mexico 21.3% (95% CI 18.2-24.4); Montevideo, Uruguay 21.9% (18.5-25.3). The range for category II and extreme obesity was between 2.9% and 15.7%.	Latin America	Obesity is an independent factor contributing to ADL disability. Category I and Category II obesity are presented separately. We added both percentages to report prevalence of obesity overall.
Morabia, A[26]	2005	35-74 y/o	Cross-sectional yearly interviews of people in Switzerland between 1993-2003	WHO cut-points	Prevalence of obesity increased from 9% in 1993 to 15% in 2003 in men; in women it increased from 7% to 11%.	Europe	Age adjusted trends.
Andreyeva, T[21]	2007	≥ 50 y/o	Cross sectional data study using data from the first wave of SHARE (2004) a panel study including eleven countries in Europe.	WHO cut-points	Obesity was present in 16.2% of men and 17.8% of women. The prevalence for each country was as follows: 17.9% in Austria, 14% in Denmark, 15.1% in France, 16.9% in Germany, 16.8% in Greece, 15.2% in Italy, 13% in the Netherlands, 20.2% in Spain, 12.8% in Sweden, 13% in Switzerland; for women the prevalence was: 19.7% in Austria, 13.3% in Denmark, 15.1% in France, 17.4% in Germany, 21.9% in Greece, 17.1% in Italy, 16.5% in the Netherlands, 25.6% in Spain, 14.4% in Sweden, 12.3% in Switzerland	Europe	
Charles, MA[22]	2008	≥ 18 y/o	Uses cross sectional data from 4 national surveys in France (1997, 2000, 2003,	WHO cut-points	Prevalence of obesity increased from 8.6% (95% CI 8.2-8.8) in 1997 to 13.1% (95% CI 12.7-	Europe	Parallel increase in obesity trends for men and women between 1997-2003 but slightly lower in

Author	Year	Age Inclusion	Type of Study	BMI cut-off points	Mean BMI or prevalence	Region	Notes
			2006) to examine trends in obesity		13.5) in 2006.		men between 2003-2006.
Lang, IA[25]	2008	≥ 65 y/o	Longitudinal study using data from ELSA to predict mortality and disability by BMI status	WHO cut-points	Prevalence of obesity at baseline was 19.4% for men and 28.9% for women.	Europe	Obesity at baseline was related to higher risk of mortality and disability.
Kotseva, K[20]	2009	<= 70 y/o	Cross sectional study using EUROASPIRE I,II and III data	WHO cut-points	Age and diagnosis adjusted: 25% [95-96]; 32.6% [99-00]; 38% [06-07]	Europe	EUROASPIRE I-III are cross-sectional studies conducted in acute hospital in 8 European countries (Republic, Finland, France, Germany, Hungary, Italy, the Netherlands, and Slovenia) to identify prevalence of cardiovascular risk factors. Interviews were conducted in 1995-96, 1999-2000 and 2006-07. Large variation by country was observed. Euroaspire studies are hospital based convenient samples
Dugravot, A[23]	2010	45-65 y/o	Longitudinal	WHO cut-points	Obesity rates for men were 3.4% and 7.7% for managers and unskilled workers respectively at age 45 and 9.5% and 18.1% for managers and unskilled workers respectively at age 65. Statistically significant increases in BMI trajectories in 20 year period for men and women by education and occupation category.	Europe	Examined socioeconomic differences in trajectories of BMI and obesity between age 45 and 65 in France.
Hubbard, RE[24]	2010	≥ 65 y/o	Cross Sectional study using wave 2 (2004) of the ELSA study	WHO cut-points	Mean BMI for the sample was 27.5 (95% CI 27.4-27.5). Prevalence of obesity was 29.1% for women and 23.4% in men.	Europe	Analyzed the relationship between BMI and frailty and examined differences by Frailty definition used.
Gomez-Cabello, A[27]	2011	≥ 65 y/o	Longitudinal Study in Spain	WHO cut-points	Prevalence of obesity was 40.9% for women and 26.6% for men, the overall rate was 37.6%	Europe	Differences reported using waist circumference, BMI and body fat.
Banks, J[99]	2006	55-64 y/o	Cross sectional data from two studies: 2002 HRS in the US and 2002 ELSA in the UK	WHO cut-points	Prevalence is 23.0% for the UK and 31.1% for the US.	Comparison between regions - USA + Europe	Significant difference at the .01 level, controlling for income and education
Michaud, PC[28]	2007	≥ 50 y/o	Cross sectional data comparing data from the HRS (2004) and the first wave of SHARE (2004)	WHO cut-points	Obesity was present in 30.7% of men in the USA and 17.6% in Europe and 37.9% of women in USA and 24.2% of women in Europe. The prevalence of obesity by European country for men was: 19.8% in Austria,	Comparison between regions - USA + Europe	BMI is corrected for self-report bias using formula derived from NHANES study (Cawley & Burkhauser, 2006)

Author	Year	Age Inclusion	Type of Study	BMI cut-off points	Mean BMI or prevalence	Region	Notes
					18.6% in Germany, 15.8% in Sweden, 15.3% in the Netherlands, 20.8% in Spain, 15.6% in Italy, 16.2% in France, 17.5% in Denmark and 19.2% in Greece. The prevalence of obesity by European country for women was: 26.9% in Austria, 22.9% in Germany, 21.5% in Sweden, 23.2% in the Netherlands, 33.6% in Spain, 23.4% in Italy, 20.3% in France, 18.2% in Sweden and 31.2% in Greece.		
Avendano, M[100]	2009	50-74 y/o	Cross sectional data in 2004 comparing three studies: HRS in USA, ELSA in England and SHARE in Europe	WHO cut-points	Prevalence of obesity: 28.8% in US, 26.1% in UK and 17.8% in Europe	Comparison between regions - USA + Europe	
Young, TK[29]	2007	≥ 18 y/o	Cross sectional study using 4 studies of Inuit people (1 in Alaska, 2 in Canada and 1 in Greenland) conducted between 1990 and 2001	WHO cut-points	A total of 15.8% of Inuit men had obesity while 25.5% of women had obesity.	Multi-country study of Inuit people	No significant differences between countries were observed
Stewart, ST[3]	2009	≥ 18 y/o	Uses cross sectional data to estimate trends in Obesity and estimate impact on mortality in 2020	WHO cut-points	25.2 [1973-1979]; 26.5 [1990]; 27.9 [2000]; 28.3 [2005]	North America	Forecasts of life expectancy in the United States for a representative 18-year old assuming trends in smoking and BMI remain constant. Project 45% of US population will be obese by 2020. NHANES

CNPHS = Canadian National Population Health Survey

NHANES = National Health and Nutrition Examination Survey (USA)

ELSA = English Longitudinal Study of Ageing

SHARE = Survey of Health, Ageing and Retirement in Europe

SABE = Health, Well-being and Ageing Survey (Latin America and the Caribbean)

MHAS = Mexican Health and Ageing Study

Table 2

Summary of literature review of studies analyzing the relationship between obesity and disability

Author	Year	Age of participants	Type of Study	Obesity measure used	Disability measure used	Relationship between obesity and disability	Notes
Ferraro, KF[37]	2002	25-74 y/o	Longitudinal study	BMI with WHO cut-off points	A total of 19 items from the Stanford Health Assessment Questionnaire Disability Index. Nine items were grouped to measure lower-body disability and ten items were grouped to measure upper-body disability.	At baseline, obesity was related to upper-body disability but not lowerbody disability. Overtime, both underweight and obesity were related to upper and lower-body disability.	Relationship between overweight and disability was not consistent for the different groups analyzed.
Visscher, TL[40]	2004	Adults 20-92 y/o, dichotomized using 65 as cut-off point	Longitudinal study	BMI with WHO cut-off points	Receiving any work disability pension from the National Social Insurance Institutions in Finland	Overweight and obesity were related to higher risk of work disability.	Risk of work disability was higher for younger adults (<65 y/o) compared to older adults (>65 y/o). Effect of obesity on onset of cardiovascular disease, long-term medication use and unhealthy life years was also assessed.
Sturm, R[39]	2004	50-69 y/o	Longitudinal study	BMI with WHO cut-off points	Difficulty with ADL or positive reports of "impairment or health problem that limits the kind/amount of paid work."	The probability of ADL disability was 50% higher for men with BMI between 30-35, compared to men with BMI between 20-25. The probability increased to 300% if BMI was > 35. For women the effect is larger with double the risk for women with BMI between 30-35 and four times the risk for women with BMI >35.	Uses HRS study
Reynolds, SL[38]	2005	≥ 70 y/o	Longitudinal study	BMI using WHO cut-off point of 30 to create 2 categories (Obese vs. Non-obese)	Difficulty in one or more ADL	Incidence of disability between 1993 and 1998 was higher for obese adults compared to non-obese adults (16.7% vs. 12.7%). Obese older adults also had significantly higher probability of becoming disabled compared to non-obese adults.	Obesity had little effect on life expectancy. Obesity also affected likelihood of recovering from disability.
Wilkins, M[42]	2005	≥ 45 y/o	Conducts crosssectional analysis using data from CCHS in 2003 and longitudinal analysis using data from the NPHS waves 1-4	BMI with WHO cut-off points	ADL/IADL	Dependency in ADL/IADL was almost the same for older adult who were underweight and those with obesity class III.	Controlling for confounders in stepwise for at the end of analysis. Obesity was predictive of dependency in ADL/IADL over time.

Author	Year	Age of participants	Type of Study	Obesity measure used	Disability measure used	Relationship between obesity and disability	Notes
Al Snih, S[36]	2007	≥ 65 y/o	Longitudinal study	BMI with WHO cut-off points	Difficulty with one or more ADL	A "U" shaped relationship between BMI and disability was observed. Disability-free life expectancy was highest for older adults with BMI between 25-30.	Used sample with non-Hispanic Whites, African-Americans and Hispanics.
Lang, IA[25]	2008	≥ 65 y/o	Longitudinal study	BMI with WHO cut-off points	Self-reported and measured physical function was assessed. Self-reported difficulty in one or more ADL. Measured physical function was assessed through the SPPB, a score ≤ 7 was considered disability.	Rise in poor self-reported and measured physical function with increasing BMI. Over time obese were more likely to develop disability compared to normal-weight adults.	Uses ELSA study
Walter, S[41]	2009	≥ 55 y/o	Longitudinal study	BMI with WHO cut-off points and WC divided in three categories for men and women separately.	ADL from the HAQ-DI Index. HAQ-DI score ≥ 0.5 considered disability	Obesity doubles the risk of disability over time.	BMI also decreases the probability of recovery from disability over time.
Al Snih S[44]	2010	≥ 65 y/o	Cross sectional study using data from the SABE study that included 6 cities in Latin America	WHO cut-points, separates category I (BMI between 30 and 34.9) from category II and extreme obesity (BMI ≥ 35)	Difficulty in one or more ADL	Obesity is an independent factor contributing to ADL disability. Category I and Category II obesity are presented separately.	Variation by country observed, however relationship present in all countries.
Himes, CL[49]	2000	≥ 70 y/o	Cross-sectional study	BMI with WHO cut-off points	Self-reported limitations in one or more ADL or any difficulty with one or more items of the Nagi disability scale.	As BMI increase ADL limitations increase	Effect of obesity on each ADL was analyzed and on ADL and Nagi activities separately. Effect of obesity on five medical conditions is also analyzed.
Pedersen, AN[51]	2002	80 y/o	Cross-sectional study	BMI with 3 categories: <24 kg/m², 24-29 kg/m², >29 kg/m² and body fat mass and fat-free mass measured with bioelectrical impedance.	Measured with muscle strength, physical activity, functional ability and selfreported functional ability.	Higher body weight and higher BMI were correlated with better muscle strength. Individuals with BMI <24 had a tendency of having higher muscle strength compared to individuals with BMI >24, differences were only statistically significant for women. There was no difference in physical activity or functional ability by BMI group.	
Chen, H[47]	2002	65-92 y/o	Cross-sectional study	Waist circumference divided in	A 12 item ADL questionnaire adapted from Katz scale. Score divided in three categories: 1) no disability, 2) some	Weight change after age 50 had a "U" shaped relationship with disability. Abdominal obesity and	Representative sample of Hispanics in Massachusetts. Women

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				quintiles for men and women separately or BMI with WHO cut-off points	disability and 3) considerable disability	weight gain were associated with greater disability in men and women. BMI greater than 35 was associated with greater disability only among women.	had a higher disability score compared to men. Higher proportion of women compared to men had obesity. However, men had a higher average waist circumference compared to women. Women reported higher average weight change compared to men.
Zoico, E[50]	2004	Women 67-78 y/o	Cross sectional study	BMI with WHO cut-off points and fat percentage measured with DXA	Combination of 3 scales: ADL, three Rosow and Breslau functional items and IADL	Both higher BMI values and higher fat percentage were associated with higher prevalence of disability	
Woo, J[54]	2007	≥ 65 y/o	Cross-sectional study	BMI using cut-off point previously reported for Asian populations	Physical activity level determined through the PASE scale or difficulty performing one of the following: walking 2-3 blocks, climbing 10 steps, meal preparation, doing heavy house work and shopping.	Older adults with category 1 and category II obesity (BMI between 25-29.9 kg/m² and ≥ 30 kg/m²) had greater number of impairments performing the different activities. A "U" shape relationship between BMI and physical performance is reported.	Study using men and women in Hong-Kong. Additional analyses show that fat mass associated with physical function while apendicular muscle mass was not.
Alley, DE[45]	2008	≥ 60 y/o	Cross-sectional study using data to analyze disability trends in the United States	BMI with WHO cut-off points	Two types of disability indicators: 1) functional limitations 2) ADL	At baseline, prevalence of functional impairment was lowest among the normal weight adults (26.7%) and increased for overweight adults (27.4%) and obese adults (36.8%); prevalence of ADL impairment was 5% for underweight, 4.3% for overweight and 6% for obese older adults. At follow up, the prevalence of functional impairment was 26.6% for normal weight adults, 25.8% for overweight and 42.2% for obese older adults; prevalence of ADL impairment was 3.5% in normal weight, 3% in overweight and 5.5% in obese.	"J" shaped observed in the relationship between obesity and disability reported in other studies, for ADL disability at baseline and follow-up and for functional impairment at follow-up. Over time the prevalence of functional impairment increased for obese individuals, but no change was observed for ADL impairment.
Chen, H[48]	2008	≥ 60 y/o	Cross-sectional study	Sex specific quartiles and WHO cut-off points in addition to waist circumference	A total of 19 questions to assess the level of difficulty in performing physical or mental task without using special equipment were used to measure functional status. The items were classified into five domains: 1) ADL, 2) IADL, 3) Leisure and social activities, 4) Lower extremity mobility, 5) general physical activities. Disability was defined	BMI was positively associated with all measures of functional disability in women and with disability in all domains but ADL and IADL in men.	Waist circumference also associated to disability. Waist circumference is suggested as a stronger indicator of disability for women compared to men.

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					as with one or more activities within a given domain.		
Rolland, Y[52]	2009	Women 75 y/o or older	Cross-sectional study	Percentage body fat above the 60th percentile measured with DXA	Difficulty in 3 or more mobility activities (walking, climbing stairs, going down stairs, rising from chair or bed, picking up object from floor, lifting heavy object or reaching for objects).	Compared with the group with normal body composition, obese women had 44-79% higher odds of having difficulty with functional measures.	Association between obesity, sarcopenia and their combination with disability was examined. Obesity alone and sarcopenia with obesity both increase the risk of disability.
Berraho, M[46]	2010	≥ 65 y/o	Cross-sectional study	BMI with WHO cut-off points	Hierarchical index aggregating three domains of disability into a single measure: mobility, ADL and IADL. Individuals were considered dependent if they could not perform at least one activity of the domain without help.	The highest proportion of independent older adults was among those with a BMI range between 25-30 kg/m². The highest rates of mobility disability were observed in obese older adults.	Differences observed in the relationship between obesity and disability depending on type of disability measured.
Vincent, HK[53]	2010	≥ 60 y/o	Literature Review article with cross-sectional and longitudinal studies	BMI, body fat percentage or fat mass.	Mobility disability measure with at least one of the following: walk time, walk distance, transfers, chair rise to timed-up-and-go test to stair climb.	Cross-sectional studies show that obesity is associated with poor lower extremity mobility in older men and women. Most longitudinal studies reported that higher adiposity was related to declining mobility over time. Walking, stair climbing, and chair rise were especially affected if BMI was greater than 35 kg/m². Mobility impairment in older obese adults was more common for women compared to men.	A few interventional studies reviewed provide evidence that weight loss is related with better mobility.
Wee CC[43]	2011	≥65 y/o	Longitudinal Study	BMI with WHO cut-off points	Difficulty with one or more ADL or Difficulty with one or more IADL	Overweight and obesity were associated with new or progressive ADL and IADL disability in a dose-dependent manner, particularly for white men and women.	Obesity was not associated with mortality, except for those with at least moderately severe obesity.

CCHS = Canadian Community Health Survey

NPHS = National Population Health Survey in Canada

ADL = Activities of Daily Living

IADL = Instrumental Activities of Daily Living

DXA = Dual energy X-ray absorptiometry

ELSA = English Longitudinal Study on Ageing

HAQ-DI = Health Assessment Questionnaire Disability Index