

# Health & Fitness Journal of Canada

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Volume 6

January 30, 2013

Number 1

## SYSTEMATIC REVIEW

### **Sex differences in habitual physical activity of the elderly: Issues of measurement, activity patterns, barriers and health response.**

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#### **Abstract**

A systematic review of sex differences in the habitual physical activity of the elderly covers articles published between 1966 and 2012. Both subject sampling and assessments of physical activity are liable to sex biases. Questionnaires have large systematic errors; often, they were designed for male populations, so that the common activities of many elderly women may be ignored. Pedometer/accelerometers generally give more accurate information on activity patterns than questionnaires. But again, there are sex differences in the minimum periods of recording needed to overcome effects of the weekly routine, adverse weather conditions and seasonal variations. Men and women also differ in the times that they allocate to activities that are not well recorded by personal monitors. Doubly-labelled water (DLW) studies provide the gold standard of metabolic measurement, but particularly in elderly women, the daily intensity of physical activity rises so little above the resting state that DLW estimates of leisure activity lack precision. When sex differences in patterns of physical activity are analyzed on a geographic basis, there seem few differences between the developed societies of North America, Japan, Europe and other parts of the world. All regions show substantial sex differences in the types of physical activity performed, with men focused more upon sport, and women devoting more time to housework and walking; however, such differences seem attenuated in the very old. The overall weekly volume of physical activity is some 10% greater in elderly men than in women of similar age, and moderate or vigorous activity, although limited in both sexes, is more likely to be reported and/or observed in men. Involvement in Masters competition demonstrates sex differences in the choice of activities and participation rates that parallel those seen in the general elderly

population. Attempts to demonstrate secular trends in habitual activity have to date had limited success because observations have covered relatively short periods, and comparisons have often been vitiated by year-to-year changes in measurement procedures. Studies of factors encouraging and inhibiting physical activity have often been hampered by failure to use sound behavioural models. Many older men are still attracted by the competitive aspects of physical activity, but valued aspects for women are companionship, and the aesthetic and health benefits of physical activity. Women report more barriers to exercise than men, emphasizing such issues as the perceived dangers of physical activity, costs and the lack of a companion and transport. The active elderly gain many health advantages over their sedentary peers, including higher levels of fitness, a later onset of dependency, and reduced risks of all-cause mortality, an adverse metabolic risk profile, cardiovascular disease, peptic ulcers, benign and malignant neoplasms, osteoporosis and sarcopenia. Outcomes sometimes differ between men and women, because women start from a poorer level of health, and they are less likely to engage in the moderate to vigorous physical activity needed for certain improvements in health status. From the standpoint of policy, a large proportion of the elderly, both men and women, take much less than the minimum weekly volume of activity that has been recommended for their health. There is thus great scope to find new ways of stimulating a greater interest in physical activity among the elderly, taking account of sex-specific preferences and perceived barriers to exercise. There remains a need to explore ways in which currently available information about habitual activity patterns may have been distorted by sex-specific sampling and sex-related differences in responses to questionnaires and

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personal monitors. It will be particularly interesting to obtain accurate longitudinal data, exploring how far physical activity patterns are changing in response to both health promotional efforts and changes in the social status of elderly women. **Health & Fitness Journal of Canada** 2013;6(1):3-71.

*Keywords:* Accelerometer; Activity patterns; All-cause death rates; Cardiovascular disease; Dependency; Fitness levels; Health outcomes; Intensity; Masters athletes; Metabolic risk factors; Neoplasms; Osteoporosis; Pedometer; Perceived barriers; Physical Activity Questionnaire; Sarcopenia; Seasonal Effects; Secular trends; Volume of physical activity.

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### Background

Whether examining the general population or elite athletes, young and middle-aged women generally engage in less physical activity and have a smaller aerobic power and muscle strength than their male peers. This is the opposite of what has been observed in some animal species such as rodents, suggesting that in humans the influence of social roles may outweigh hormonal factors (Bowen et al., 2011). A large proportion of seniors engage in little deliberate exercise. But even amongst those who are active, casual observation suggests the persistence of important sex differences in patterns of habitual physical activity. Some active pursuits attract mainly women, and in others the participants are mainly men. This reflects not only socio-cultural influences, but also sex-related differences in body size, body fat content, and hormonal milieu (Shephard, 1994, 2000b; Shephard et al., 1988).

A clear understanding of these sex differences is important for those making public health recommendations and/or designing physical activity programmes for the elderly. We have previously made a detailed analysis of sex differences in exercise behaviours and health outcomes for seniors aged 65-85 yr who were living in the Japanese community of Nakanojo (Aoyagi and Shephard, 2013; Yasunaga et al., 2008). The objective of the present paper is to assess the generality of these observations through a systematic review of published reports on the habitual physical activity of elderly men and women living in other physical and socio-cultural environments around the world.

### Search Tactics

The data bases of HealthStar Ovid, PubMed, Sport Discus, Sport NZ Sport & Recreation Knowledge Library and SportScan were reviewed over the period from 1966 to 2012, using as key words the terms *Ageing, Aged, Seniors or Elderly; Sex characteristics, Sex differences, Sex factors or Gender differences; and Physical activity or Motor activity*. This tactic yielded a total of 2697 hits. Detailed analysis was restricted to the 2535 articles published since January 1992, although key papers from the 162 earlier reports have also been included in this review. All relevant articles dealing with human subjects were considered, irrespective of the language of publication, provided that abstracts were available. This material was supplemented by scanning the bibliography of these articles, correspondence with key investigators and a searching of the authors' own extensive personal files.

After a review of titles and abstracts, a total of 424 articles was retained for detailed consideration and the findings

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from 213 of these were finally included in the present review. These reports provided information on clearly delineated sex differences in habitual physical activity among subjects aged > 65 yr. Specific issues that were evaluated included methods of sampling and activity measurement, the type, volume and intensity of effort reported, the status of elderly athletes, perceived correlates and barriers to physical activity, and outcomes in terms of selected measures of fitness and health.

### **Technical Issues of sampling and measurement**

Conclusions concerning sex differences in the physical activity of elderly individuals can be compromised by a variety of technical issues, including differential population sampling and systematic errors in the three main methods of estimating habitual physical activity [questionnaires of varying complexity, personal monitors such as pedometers and accelerometers, and the ingestion of doubly-labelled water (DLW)]. Some authors have also used attained fitness as a criterion of habitual activity, although one study of Californian residents (846 men and 1246 women aged > 55 yr) found that the reported 1-yr and 7-day leisure energy expenditures accounted for less than 5% of the variance in maximal aerobic power (Tager et al., 1998).

### **Sampling**

Reported or perceived illness, lack of a telephone, removal from the residence selected by the investigator, lack of transport and unwillingness to leave home can all restrict the participation of older individuals in a physical activity survey, making the final sample less than

representative of a given community. Several of these factors appear to have a greater impact upon women than men.

Thus, in a small study of non-institutionalized elderly Ontarians, personal characteristics favouring participation in a survey that included walking and treadmill tests were male sex, a higher socio-economic level and single rather than married status (Koval et al., 1992). Respective participation rates at ages 55-64, 65-74 and 75-84 yr were 71.5, 69.7 and 59.7% for men and 57.9, 75.3 and 55.2% for women, and the percentages completing the test protocol were 41.9, 34.4 and 21.3% of men, and 34.9, 34.1 and 14.7% of women.

A similar differential response to a physical activity questionnaire was seen in the Nakanojo study of Japanese subjects aged 65-85 yr, with 73.2% of men and 66.4% of women returning the questionnaires for analysis (Yasunaga et al., 2007).

### **Questionnaires**

Questionnaire estimates of habitual physical activity are known to show relatively weak coefficients of correlation with more objective measures of physical activity such as pedometer/accelerometer counts, DLW estimates of energy expenditures or estimates of food intake (see Shephard, 2003; Shephard and Aoyagi, 2012). Many physical activity questionnaires also show large systematic errors relative to alternative methods of measurement (Table 1). Issues include the types of activity that are detected, the reliability of the instrument, and the absolute validity of the estimates that are made.

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### *Types of activity*

In one Swiss study, it was noted that if the questionnaire emphasized participation in sport, there would be a systematic under-estimation of energy expenditures in women (where the main activities were walking, cycling and housework) (Abel et al., 2001). In

small group of 10 Dutch men and 11 women aged 60-80 yr yielded much higher scores for the women than for the men (Schuit et al., 1997). This difference was not substantiated by DLW measurements, and the authors suggested that when scoring the PASE questionnaire, undue weight was given to

**Table 1: Systematic errors in questionnaire estimates of habitual physical activity relative to measurements made by personal monitors or ingestion of doubly-labelled water.**

| Author                  | Participants and Age   | Technique   | Standard value  | Finding   |
|-------------------------|--|---|---|---|
| Ainsworth et al. (1993) | 28 M 50 F<br>21-59 yr<br>Minnesota residents                         | College Alumnus Questionnaire                                 | Caltrac accelerometer (14d record) & physical activity record | Accelerometer values and activity records 3.0-5.3 times larger than questionnaire data, no sex difference in bias. No comment on age effects.   |
| Bassett et al. (2000)   | 96 M & F<br>25-70 yr<br>Knoxville residents                          | College Alumnus Questionnaire                                 | Yamax pedometer (7d record)                                   | Distance walked underestimated by questionnaire<br>1.56 vs. 4.02 km·d <sup>-1</sup> (M) 1.30 vs. 4.32 km·d <sup>-1</sup> (F)<br>No comment on age effects   |
| Wareham et al. (2002)   | 84 M, 89 F<br>58.8 ± 7.9 yr<br>55.4 ± 6.7 yr<br>Norfolk UK residents | European PA Questionnaire-2                                   | Heart rate record for 16 h waking day                         | Self report 13.6 MET·h·d <sup>-1</sup> (M),<br>8.2 MET·h·d <sup>-1</sup> (F)<br>HR gross 38.4 MET·h·d <sup>-1</sup> (M),<br>28.5 MET·h·d <sup>-1</sup> (F)<br>HR net 22.4 MET·h·d <sup>-1</sup> (M) 12.5 MET·h·d <sup>-1</sup> (F)  |
| Yasunaga et al. (2007)  | 65-85 yr<br>61M, 86 F<br>Nakanojo residents                          | P.A. Questionnaire for Elderly Japanese                       | Pedometer/ accelerometer (worn 24 h·d <sup>-1</sup> for 1 yr) | Questionnaire over-estimated both light and vigorous activity by factor of 3, similar errors in M and F   |
| Lee et al. (2011)       | Review of 6 studies  | International P.A. Questionnaire                              | Accelerometer using Freedson, Trost or Swanson cut-offs       | IPAQ over-estimated moderate and vigorous physical activity by average of 84%. No sex difference of systematic error in 2 studies   |
| Katz et al. (2012)      | 134 Amish,<br>154 Non-Amish Ohioan adults, ?age                      | International P.A. Questionnaire                              | Pedometer   | IPAQ over-estimated by a factor of 3.5 (M), 3.3 (Amish F), 2.9 (Non-Amish F)  |
| Starling et al. (1999)  | 32 M, 35 F<br>45-84 yr<br>Physically active Vermont residents        | Yale P.A. Survey and Minnesota Leisure-time PA Questionnaire  | Doubly-labelled water   | Yale Survey on average matched DLW estimate, but wide inter-individual range of discrepancies (-5.4 to + 6.3 MJ·d <sup>-1</sup> of active energy expenditure).<br>Minnesota Questionnaire under-estimated active energy expenditure (average of 3.1 MJ·d <sup>-1</sup> M. 2.0 MJ·d <sup>-1</sup> F), also wide scatter<br>No comment on age effects |
| Colbert et al. (2011)   | 12 M, 44 F<br>>65 yr<br>Wisconsin residents                          | Yale, CHAMPS and Modified Physical Activity Scale for Elderly | Doubly-labelled water   | All 3 questionnaires had very low coefficients of correlation with DLW estimates of active energy expenditure (r = 0.07 to 0.28)  |

contrast, a trial of the PASE (Physical Activity Scale for the Elderly) survey on a

reports of “heavy housework” and “caring for others.”

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### *Reliability*

An evaluation of the 3-4 week reliability of responses to the questionnaire used in the 1982 Canada Fitness Survey (Weller and Corey, 1998) suggested that men generally reported leisure activity more reliably than non-leisure activity, whereas the reverse was true for women. Men also reported strenuous activity more consistently than women (respective test-retest coefficients 0.85 vs. 0.31).

Agreement of Baecke questionnaire reports over an 11-month interval was evaluated in 134 Dutch subjects ranging broadly in age from 20-70 yr (Pols et al., 1995). Overall activity tertiles showed closer test-retest agreement for men (70.5%) than for women (63.4%); men gave more consistent information on sport participation ( $r = 0.81$  vs.  $0.65$ ) and women provided more consistent reports on their leisure activity ( $r = 0.71$  vs.  $0.81$ ).

### *Quantitative validity*

Two U.S. reports evaluated the Paffenbarger questionnaire, where the daily distance walked (expressed in city blocks), the number of stairs climbed and sport participation are the determinants of a composite physical activity score, expressed as a gross weekly energy expenditure. The values (as reported by middle-aged rather than elderly adults) were 3.0 to 5.3 times smaller than those measured more objectively by Caltrac accelerometer and activity records (Ainsworth et al., 1993 ; Bassett et al., 2000). Despite sport participation being one of the items assessed, male and female subjects each showed large and rather similar discrepancies from criterion data.

A comparison of the European Physical Activity Questionnaire 2 with heart-rate-

based estimates of energy expenditure also indicated an under-estimation of energy expenditures by the questionnaire, with self-reports being less reproducible in men than in women (Wareham et al., 2002).

In contrast, other questionnaires have exaggerated the amount of physical activity undertaken relative to pedometers or DLW measurements (Table 1). A Japanese language questionnaire (Yasunaga et al., 2007) yielded a 3-fold exaggeration of physical activity relative to pedometer/accelerometer data, with rather similar sized errors for light and moderately vigorous effort and for men and women.

The International Physical Activity Questionnaire (IPAQ) has sometimes been thought to have a greater absolute accuracy than its rivals. A review of this instrument (Lee et al., 2011) focused upon the times spent in activities classed as having a moderate or vigorous intensity; 3 of 6 such comparisons from various countries included some older subjects. On average, there was an 84% over-estimation of moderate and vigorous activity, with no sex difference in the extent of exaggeration in the 2 reports where this point was examined (Lee et al., 2011). Katz et al. (2012) analyzed IPAQ data for Amish and non-Amish subjects in their mid-50s. Pedometer step counts were also recorded. We have converted the latter information to MET-mins of physical activity, based on data for our elderly subjects that show 1 MET-min as equivalent to the taking of 34 steps in men and 36 steps in women (*unpublished data*). Using this conversion factor, the IPAQ over-estimated energy expenditures by a factor of 3.5 in both Amish and non

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Amish males, by 3.3 in Amish women, and 2.9 in non-Amish women.

Starling and colleagues (1999) compared two U.S. questionnaires (the Minnesota Leisure Time Physical Activity Questionnaire and the Yale Physical Activity Survey) with estimates of physical activity based on DLW in a small sample of physically active older adults. Responses to both instruments showed a wide scatter relative to DLW. The Minnesota questionnaire gave a substantial under-estimate of energy expenditures (averaging 3.1 MJ·d<sup>-1</sup> in men and 2.0 MJ·d<sup>-1</sup> in women) (Starling et al., 1999). The Yale questionnaire yielded approximately the same average leisure-time energy expenditures as the DLW method, but again there were wide individual divergences of active energy expenditure (ranging from -5.4 to + 6.3 MJ·d<sup>-1</sup>). A further comparison of DLW estimates with the scores yielded by the Yale questionnaire, the Physical Activity Survey for the Elderly and the CHAMPS (Community Healthy Activities Model Program for Seniors) questionnaires in a sample of men and women with an average age of 74.7 yr yielded very low correlation coefficients [0.07-0.28, (Colbert et al., 2011)].

### ***Pedometers and Accelerometers***

Modern pedometer/accelerometers are sometimes thought to be relatively free of systematic error, and as noted above they are often used as criterion measurements when assessing the accuracy of questionnaire reports. However, reliability and validity can be affected adversely by reactive effects, an insufficiently long recording period, artifacts and failure to detect certain forms of physical activity.

### ***Reactivity***

One potential problem with any form of personal monitoring is reactivity to wearing of the recording device. During the first 7 days of instrumentation, some subjects choose to engage in more than their habitual level of physical activity (Clemes and Deans, 2012; Clemes et al., 2008; Clemes and Parker, 2009; Foley et al., 2010), particularly if they can observe the step count that they are accumulating (Clemes and Parker, 2009; Ozdoba et al., 2004).

Unfortunately, in order to simplify logistics, most investigators have been content to record data for no more than 10 to 15 hours per day over a total period of 4-7 days. The effect of reactivity can then be substantial, although it does not seem to differ between men and women (Clemes and Deans, 2012).

### ***Duration of recording***

A further problem is that 4-7 days of recording are insufficient to characterize the physical activity of an elderly person over an entire year. Analysis of data from the Nakanajo study shows that in elderly men and women the respective minimum requirements for 90% reliability of estimates in men and women are 105 vs. 37 days of continuous recording, 11 vs. 9 days of random recording, and 16 vs. 12 days of recording stratified by season and day of the week (Togo et al., 2008).

Against this, a second study of middle-aged Japanese subjects (average 50 yr) found that 3 days of recording was sufficient to establish the level of activity *during any given week* with a reliability of 0.80. In this latter sample, physical activity was greater during the week than on a Saturday or Sunday (Kubota et al., 2009).

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### *Artifacts and recording errors*

A pedometer or accelerometer score may be boosted by artifacts, due to vibrations encountered when travelling in a car, bus or train (Le Masurier and Tudor-Locke, 2003). This particular error is much smaller with the Yamax pedometer/accelerometer than with some other types of accelerometer.

On the other hand, pedometer and uniaxial accelerometer scores tend to under-record such non-standard pursuits as cycling, skating, load-carrying, household chores, resisted activities and work against gravity (Sirard and Pate, 2001). The prevalence of such over- and under-recording seems likely to differ between sexes, although this has yet to be documented.

### *Reliability and validity*

The criterion used to assess the accuracy of personal monitors is the metabolism of DLW. Although the latter technique has a low experimental error, it only estimates the average energy expenditure over a 2-week period, and in an elderly population where activity levels are low, a large fraction of the total energy expenditure is due to the individual's resting metabolism. Thus, a small error in the determination of resting metabolic rate can cause a substantial error in the DLW estimate of active energy expenditure.

Under ideal measurement conditions, the immediate accuracy of a pedometer or accelerometer can be high (Esliger et al., 2007). The 24-hour step count for one instrument (Kenz Lifecorder) had an intra-modal reliability (Cronbach's alpha) of 0.998 and the error in step count relative to 500 actual paces taken on a 400 m track was only  $-0.2 \pm 1.5$  steps (Schneider et al., 2003). At both moderate

and slow walking speeds, the best of several competing commercial devices showed a systematic error of only 2% over a 4.8 km walking course (Bassett et al., 1996). Some instruments had an error exceeding 10% (Bassett et al., 1996), but most were able to estimate the treadmill walking distance to within  $\pm 10\%$  and the gross energy expenditure to within  $\pm 30\%$  at a walking speed of  $4.8 \text{ km}\cdot\text{h}^{-1}$  (Crouter et al., 2003 ; Schneider et al., 2003).

Nevertheless, under free-living conditions the accuracy of pedometers and accelerometers is much poorer (McClain et al., 2007), and there can then be systematic differences of up to 2000 steps $\cdot\text{d}^{-1}$  between pedometer and accelerometer readings (Tudor-Locke et al., 2002). Inaccuracies seem particularly likely to arise if the walking pace is slow, as is quite likely in an older person (Cyarto et al., 2004). There have been several comparisons of pedometer and accelerometer data with findings using doubly-labelled water, although not all have included both men and women (Table 2).

If the goal is to examine systematic errors in the pedometer or accelerometer, rather than to calculate correlation coefficients, this requires the somewhat debatable conversion of step counts or accelerations into estimates of an individual's weekly energy expenditure (Table 2). One study of 20 premenopausal obese women (14 of whom were engaged in a walking programme) estimated the systematic error of a Caltrac accelerometer at  $0.08 \pm 1.68 \text{ MJ}\cdot\text{d}^{-1}$  on an active energy expenditure of  $4.1 \text{ MJ}\cdot\text{d}^{-1}$  (95% confidence limits of  $\pm 82\%$ ) (Fogelholm et al., 1998). A second comparison in elderly men with intermittent claudication found a fairly close correlation between the two data

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sets, with linear regression estimates showing a SE of  $\pm 516 \text{ kJ}\cdot\text{d}^{-1}$  for the pedometer and  $\pm 323 \text{ kJ}\cdot\text{d}^{-1}$  for the accelerometer (respective 95% confidence limits on an exercise expenditure of  $1.57 \text{ kJ}\cdot\text{d}^{-1}$  of  $\pm 66\%$  and

confidence limits of the regression prediction were  $\pm 60\%$ ) and systematic errors for the accelerometer were  $-1.7 \text{ MJ}\cdot\text{d}^{-1}$  (81%) and  $+1.4 \text{ MJ}\cdot\text{d}^{-1}$  (67%) using the Crouter and Freedson equations respectively. On the basis of cost relative

**Table 2: Comparisons between pedometer/accelerometer and doubly-labelled water estimates of habitual physical activity.**

| Author                            | Sample  | Apparatus  | Findings  |
|-----------------------------------|---|--|---|
| Colbert et al. (2011)             | 12 M, 44 F<br>>65 yr<br>Wisconsin residents   | Pedometer, accelerometer, Sense-wear armband<br>7 to 10d recording | Low correlations with DLW data (0.5-0.6) for all 3 devices. Systematic error on expenditure of $2.1-1.7 \text{ MJ}\cdot\text{d}^{-1}$ (Crouter equation), $+1.4 \text{ MJ}\cdot\text{d}^{-1}$ (Freedson equation); 95 % limits of regression prediction $\pm 60\%$ . No comment on sex differences. |
| Choquette et al. (2009)           | 10 M, 7 F<br>60-78 yr<br>Sherbrooke, QC       | Caltrac accelerometer<br>7d record                                 | No significant correlations with DLW data<br>Caltrac under-estimates DLW by $0.8 \text{ MJ}\cdot\text{d}^{-1}$ (M), $2.2 \text{ MJ}\cdot\text{d}^{-1}$ (F)  |
| Starling et al. (1999)            | 32 M, 35 F<br>45 - 84 yr<br>Vermont residents | Caltrac accelerometer<br>7 d record                                | Caltrac under-estimates DLW by $2.1 \text{ MJ}\cdot\text{d}^{-1}$ (M), $1.6 \text{ MJ}\cdot\text{d}^{-1}$ (F)   |
| Rafamantantanantsoa et al. (2002) | 25 M; $48 \pm 10$ yr<br>Japanese              | Accelerometer, 3d and 14d records                                  | Correlations of accelerometer with DLW 0.78, 0.83; under-estimates of accelerometer $-2.3, -2.4 \text{ MJ}\cdot\text{d}^{-1}$   |
| Fogelholm et al. (1998)           | 20<br>overweight middle-aged Finnish women    | HR monitor, pedometer, Caltrac accelerometer                       | Active energy expenditure<br>Error lowest with Caltrac<br>$0.08 \pm 1.61 \text{ MJ}\cdot\text{d}^{-1}$ relative to DLW on expenditure of $4.1 \text{ MJ}\cdot\text{d}^{-1}$   |
| Gardner & Poehlman (1998)         | Elderly U.S. claudicant men $68.7 \pm 7.3$ yr | Pedometer, accelerometer regression equations                      | Error of pedometer vs. DLW $\pm 516 \text{ kJ}\cdot\text{d}^{-1}$ (95% limits $\pm 66\%$ )<br>Error of accelerometer $\pm 320 \text{ kJ}\cdot\text{d}^{-1}$ (95% limits $\pm 41\%$ )  |

41%) (Gardner and Poehlman, 1998).

A study of men and women with an average age of 74.7 yr and an active energy expenditure of  $2.8 \text{ MJ}\cdot\text{d}^{-1}$  found an adequate categorization of physical activity when using the last 7 of 10 days data from personal monitors. However, none of the instruments yielded accurate absolute data (Colbert et al., 2011); coefficients of correlation between DLW data and estimates from the 3 types of personal monitor that were evaluated (a pedometer, an accelerometer and a Senswear armband) were only 0.48-0.63. Mean errors were around  $0.8 \text{ MJ}\cdot\text{d}^{-1}$  (95%

to accuracy, the authors of this report advocated the pedometer as the most appropriate monitor. Their study made no comment on possible sex differences in errors. Another study of 7 women and 10 men aged 60-78 yr found no statistically significant correlation between DLW and 7-day Caltrac accelerometer outputs; the Caltrac device under-estimated active energy expenditures by  $0.8 \text{ MJ}\cdot\text{d}^{-1}$  in men and  $2.2 \text{ MJ}\cdot\text{d}^{-1}$  in women (Choquette et al., 2009).

A further comparison of one-week Caltrac scores against DLW estimates of active energy expenditure in physically



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active 45-84 yr old subjects from Burlington, VT, found substantial underestimates ( $2.3 \pm 1.0 \text{ MJ}\cdot\text{d}^{-1}$  in men and  $1.6 \pm 0.7 \text{ MJ}\cdot\text{d}^{-1}$  in women (Starling et al., 1999)). These authors suggested that the Caltrac monitor failed to capture energy expended in swimming, climbing, motion other than in the vertical plane, and post-exercise. The average active energy expenditure of this sample, as estimated from DLW, was fairly high:  $5.0 \text{ MJ}\cdot\text{d}^{-1}$  in men and  $3.6 \text{ MJ}\cdot\text{d}^{-1}$  in women, and it did not seem to agree with expectations of limited active leisure that might be inferred from the corresponding maximal oxygen intakes (averages of only 28.4 in the men and 30.7  $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ , respectively). If the actual active energy expenditure had taken the form of moderate walking at a net energy cost of  $22 \text{ kJ}\cdot\text{min}^{-1}$ , it would imply that there had been more than 200 min of walking per day by the men and  $160 \text{ min}\cdot\text{d}^{-1}$  by the women.

A final comparison in middle-aged Japanese men used a new and unspecified accelerometer; 3 and 14 day estimates of total energy expenditure showed fair correlations with DLW data (0.78, 0.83, respectively), but both were substantial underestimates of the absolute DLW value ( $-2.3$ ,  $-2.4 \text{ MJ}\cdot\text{d}^{-1}$ , respectively) (Rafamantanantsoa et al., 2002).

### **Summary**

Four of 7 assessments of physical activity questionnaires were based on correlations with pedometer or accelerometer data, which themselves are vulnerable to systematic errors. These evaluations suggested substantial systematic errors in questionnaire reports, although with one exception (the study of (Bassett et al., 2000), errors did

not differ greatly between men and women (Lee et al., 2011).

Comparisons of accelerometer data with DLW measurements were complicated by the choice of equation to convert accelerations into energy expenditures. Some calculations led to a negative and others to a positive error in the accelerometer estimates, generally with wide confidence limits. However, as with the questionnaires, there was no clear indication that the systematic errors of personal monitors differed between male and female subjects.

### **Characteristics of physical activity**

Data from many parts of the world are available to examine possible sex differences in the type, volume and intensity of physical activity undertaken by elderly populations, along with the extent of their engagement in athletic competition. However, reliable information on secular trends in these several variables is very limited, and in general covers only a short time span.

### **Type of physical activity**

Sex differences in the types of physical activity performed by elderly individuals (Table 3) seem likely to vary with the cultural norms for a particular community and ways in which these may have changed over the past 50 yr.

Most of the available information has been derived from questionnaires, although there has been occasional recourse to interviews, focus groups and daily activity logs. A key factor affecting the types of activity undertaken is the age of the subject, with occupation and active transportation accounting for a substantial proportion of physical activity in some surveys of adults prior to the age of retirement. After retirement, many

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**Table 3. Sex differences in the types of physical activity performed by older individuals.**

| Author                         | Subjects & Age   | Method                 | Findings   |
|--------------------------------|--|------------------------|--|
| Yasunaga et al. (2007)         | 3084 Adults Japan, 65-89 yr  | Questionnaire          | Transportation 10.5 (M) vs. 8.9 (F) MET-h-wk <sup>-1</sup> ;<br>labour 27.3 (M) vs. 16.5 (F) MET-h-wk <sup>-1</sup> ;<br>light or moderate sports 21.0 (M) vs. 15.6 MET-h-wk <sup>-1</sup>   |
| Dallosso et al. (1988)         | 219 M, 282 F 65-74 yr; 180 M, 337 F >75 yr from UK general practice  | Interview              | Outdoor productive activity 7.4, 4.3 h-wk <sup>-1</sup> (M), 4.1, 0.5 h-wk <sup>-1</sup> (F); Indoor productive activity 4.9, 4.1 h-wk <sup>-1</sup> (M), 10.1, 8.0 h-wk <sup>-1</sup> (F); leisure 3.6, 2.8 h-wk <sup>-1</sup> (M), 1.8, 1.0 h-wk <sup>-1</sup> (F)   |
| Armstrong & Morgan (1998)      | 397 M, 619 F >65 yr from UK general practice                         | Interview              | >3 h-wk <sup>-1</sup> activity, ages 65-74, >75 yr:<br>Indoors 49, 46% (M), 89, 74% (F);<br>Outdoors 55, 33% (M), 25, 11% (F);<br>Leisure 35, 28% (M), 18, 10% (F)   |
| Wareham et al. (2002)          | 84 M, 89 F England<br>58.8 ± 8.9 yr (M),<br>55.4 ± 6.7 yr (F)        | Questionnaire          | Domestic activity 14.2 (M) vs. 62.0 (F);<br>occupation 68.9 (M) vs. 37.7 (F);<br>recreation 26.2 (M) vs. 14.0 (F) MET-h-wk <sup>-1</sup>   |
| Bélanger et al. (2011)         | Active adults England<br>16-65+ yr                                   | 2008 Health Survey     | Over age 65 yr, main sources of moderate & vigorous activity<br>walking (42% M, 45% F), housework (34% M, 39% F)<br>and exercise/sport (12% M, 11% F)  |
| Davis et al. (2011)            | 109 M, 105 F<br>70-85 yr Recruits to "better aging" project, UK      | 7-d trip log           | Active trips 3.4-3.6 per wk (M) 2.6-2.7 per wk (F)   |
| Osler et al. (1991)            | 2586 Europeans,<br>73-78 yr  | Questionnaire          | Housework 0.7-2.3 h·d <sup>-1</sup> (M), 2.6-3.9 h·d <sup>-1</sup> (F)<br>Leisure activity 0.9-2.3 h·d <sup>-1</sup> (M), 2.0-4.2 h·d <sup>-1</sup> (F)  |
| Luoto et al. (1979)            | 1704 M, 2182 E<br>45-64 yr, participants in N.Karelia study, Finland | Questionnaire          | Heavy physical activity >3 per wk 21.8% M, 14.6% F;<br>Walking >4 per wk 51.1% M, 55.3% F;<br>No leisure activity 27.7% M, 30.1% F   |
| Bak et al. (2005)              | 57,053 Norwegians<br>50-65 yr  | Questionnaire          | Sport 1.5 h-wk <sup>-1</sup> (M & F), Cycling 2 h-wk <sup>-1</sup> (M & F),<br>Walking 2.5 h-wk <sup>-1</sup> (M & F), Gardening 2 h-wk <sup>-1</sup> (M), 1.5 h-wk <sup>-1</sup> (F),<br>DIY 1.5 h-wk <sup>-1</sup> (M), 0.5 h-wk <sup>-1</sup> (F),<br>Housework 1.5 h-wk <sup>-1</sup> (M), 4.5 h-wk <sup>-1</sup> (F)  |
| van dem Homborgh et al. (1995) | 493 M, 503 F<br>65-84 yr non-institutionalized Dutch                 | Questionnaire          | Light housework 61% M, 90% F<br>Inactive 9% M, 13% F   |
| Lührmann et al. (2009)         | 153 M, 363 F<br>Giessen, Germany<br>Average age 67 yr                | Questionnaire          | Housework + Garden 126 min·d <sup>-1</sup> (M), 220 min·d <sup>-1</sup> (F)<br>Walking 30 min·d <sup>-1</sup> (M), 25 min·d <sup>-1</sup> (F)<br>Sports 46 min·d <sup>-1</sup> , 30 min·d <sup>-1</sup> (F)<br>Active energy exp. 4.4 MJ·d <sup>-1</sup> (M), 3.8 MJ·d <sup>-1</sup> (F)   |
| Booth et al. (1997)            | c. 766 Australians<br>60-78 yr                                       | Questionnaire          | Preferred activities walking (68%) and swimming (13%)<br>Similar in men and women  |
| Bentley et al. (2010)          | 2357 Australians aged 18-74 yr                                       | Self-report            | Walking >60 min-wk <sup>-1</sup> 43.8% (M), 52.2% (F)<br>Age 65-74 yr 54.4%, 25-34 yr 43.7%  |
| Ratzlaff et al. (2010)         | 4269 Canadian retirees   | Lifetime questionnaire | For lifespan, housework 28.6 (M) vs. 70.5 (F); occupation 63.9 (M) vs. 40.5 (F); sport 16.9 (M) vs. 7.3 MET-h-wk <sup>-1</sup> . For 66-70 yr, housework 35 (M) vs. 61 (F); occupation 15 (M) vs. 14 (F); sport 11 (M) vs. 6 (F) MET-h-wk <sup>-1</sup> For 75-80 yrs, housework 22 (M) vs. 20 (F); occupation 0; Sport 6 (M) vs. 0 (F) MET-h-wk <sup>-1</sup> * |
| Eaton et al. (1994)            | 1052 M, 1251 F<br>>65 yr Rural New York State                        | Questionnaire          | Walking 53.7% M, 71.1% F; gardening 13.5% M, 8.6% F;<br>golf 7.0% M, 2.6% F; cycling 4.0% M, 5.9% F;<br>swimming 1.6% M, 2.7% F; aerobics 2.1% M, 3.4% F;<br>work-related 8.2% M, 3.4% F   |
| Clark (1999)                   | 11 M, 17 F low-income US<br>55-70 yr                                 | Focus group            | Preferred activities yard work and walking (M)<br>walking (F)  |

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surveys have found walking to be the most common source of physical activity, with a selective involvement of women in housework and men in do-it-yourself home maintenance projects. A larger proportion of men than women report continuing involvement in sport. Productive household work shows some shift from women to men in the oldest age categories, when weakness of one partner in a marriage often becomes an issue.

### *Japan*

Our questionnaire analysis of 3084 elderly individuals (65-99 yr) in the town of Nakanojo (Yasunaga et al., 2007) showed substantial male-female differentials in reported energy expenditures on housework (20.6 vs. 38.2 MET-h·wk<sup>-1</sup>), other forms of physical labour (27.3 vs. 19.5 MET-h·wk<sup>-1</sup>), active transport (10.5 vs. 8.9 MET-h·wk<sup>-1</sup>) and deliberate exercise or sport (21.6 vs. 15.6 MET-h·wk<sup>-1</sup>). The largest sex differences were in the energy expended on light (11.2 vs. 25.3 MET-h·wk<sup>-1</sup>) as opposed to moderate or somewhat heavy housework (9.3 vs. 12.0 MET-h·wk<sup>-1</sup>). In terms of involvement in sports and deliberate exercise, men reported about one third greater energy expenditures than women on each of light exercise (13.6 vs. 10.0 MET-h·wk<sup>-1</sup>), moderate or somewhat strenuous exercise (6.1 vs. 4.8 MET-h·wk<sup>-1</sup>) and resistance exercise (1.2 vs. 0.9 MET-h·wk<sup>-1</sup>).

### *United Kingdom.*

Several studies from the U.K. had similar findings to the Nakanojo study. A survey of 70-yr-olds from Scotland, published in 1973, found that very few men were helping their wives with housework, cooking or shopping. In contrast, the men were more likely to go

out every day and to have outside interests, although the women were more likely to join clubs than the men (Loneragan et al., 1973).

A survey of 397 men and 619 women who were attending family physicians in the Nottingham area of the UK looked at the respective percentages of individuals who reported engaging in more than 3 h·wk<sup>-1</sup> of indoor, outdoor and leisure activity. For those aged 65-74 yr, values were 49%, 55% and 35% in men, and 89%, 15% and 18% in women. In those aged >75 yr, the corresponding figures were 46%, 33% and 28% for men and 74%, 11% and 10% in women (Armstrong and Morgan, 1998 ; Bennett, 1998). A further analysis of the Nottingham data looked at the hours committed to 3 categories of physical activity: outdoor productive work (gardening, house or car maintenance), indoor productive activity (housework or home maintenance) and leisure (bowls, cycling, swimming or deliberate walking). In those aged 65-74 yr, the respective time allocations were 7.4, 4.9 and 3.6 h·wk<sup>-1</sup> in men, and 4.1, 10.1 and 1.8 h·wk<sup>-1</sup> in women. For those >75 yr, the corresponding figures were 4.3, 4.1 and 2.8 h·wk<sup>-1</sup> in men and 0.5, 8.0 and 1.0 h·wk<sup>-1</sup> in women (Dallosso et al., 1988).

A smaller questionnaire study of middle-aged English adults (Wareham et al., 2002) found a gross preponderance of domestic activity in women [respective energy expenditures of 14.2 (M) vs. 62.0 (F) MET-h·wk<sup>-1</sup>]. On the other hand, the men reported greater occupational activity [68.9 (M) vs. 37.7 (F) MET-h·wk<sup>-1</sup>] and recreational energy expenditures [26.2 (M) vs. 14.0 (F) MET-h·wk<sup>-1</sup>] than the women.

The most recent British study (completed in 2008) examined a

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nationally representative sample of adults over the age of 65 yr who reported meeting at least the recommended minimum weekly volume of physical activity. Whether because of social change or the selection of active individuals, the findings differed slightly from the results of earlier surveys. The major sources of moderate and vigorous physical activity in men and women respectively were walking (42%, 45%), housework (34%, 39%) and deliberate exercise or fitness activities (12%, 11%) (Bélanger et al., 2011). The men showed a substantial jump in the contributions of both walking (42% vs. 32%) and housework (34% vs. 24%) from the 55-64 yr age group to those aged >65 yr, this being explained almost entirely by a corresponding drop in occupational activity. Women showed a much smaller change in physical activity patterns at retirement, although in their case also the occupational component dropped, from 13% to 3%.

In a sample of older employed adults (average age 60.4 yr) from the relatively rural area around Norwich, UK, a surprisingly large 26.8% of men and 26.5% of women engaged in active commuting to work (Panter et al., 2011). Active commuting was associated with a habit of cycling or walking, a travel distance <4 km, and a quiet, flat road to work. Fewer men but more women who were classed as unskilled or partly skilled were likely to engage in active commuting.

However, in citizens of Bristol over the age of 70 yr (where almost all of the sample had taken retirement), a 7-day trip-log indicated that men made somewhat more frequent active trips than their female counterparts (3.4 vs. 2.6 active trips per wk) (Davis et al., 2011).

### *Europe*

A survey of people living in 19 European towns and cities examined the activities undertaken by those born in 1913-1918 (i.e. about 75 yr of age at the time of the survey). The women spent more hours per day on physically active tasks than men, including more time on housework (2.6-3.9 h·d<sup>-1</sup> versus 0.7-2.3 h·d<sup>-1</sup> for men), but in this sample the women also engaged in more leisure-time activities (2.0-4.2 h·d<sup>-1</sup> versus 0.9-2.3 h·d<sup>-1</sup> for men) (Osler M, 1991).

In Giessen, Germany, 126 men and 363 women with an average age of 67 yr reported similar walking times (30 vs. 26 min·d<sup>-1</sup>), but sport involvement was greater in the men (46 vs. 30 min·d<sup>-1</sup>) and the men spent less time than the women on housework and gardening (1126 vs. 220 min·d<sup>-1</sup>). Respective active energy expenditures were 4.4 MJ·d<sup>-1</sup> and 3.8 MJ·d<sup>-1</sup> (Lührmann et al., 2009).

Among a sample of 493 male and 503 female residents of Arnhem, Holland, aged 65-84 yr, the most striking sex difference was in light housework, reported by 90% of women, but by only 61% of men; 9% of the men and 13% of the women had no recreational physical activities (van dem Hombergh et al., 1995).

Younger samples from Northern Europe showed smaller sex differences in active leisure pursuits. A large population of Danish adults aged 50-65 yr (n = 57,053) who were participating in a prospective cancer study reported similar times devoted to sport (1.5 h·wk<sup>-1</sup>), cycling (2 h·wk<sup>-1</sup>) and walking (2.5 h·wk<sup>-1</sup>) in men and women (Bak et al., 2005). However, the men spent more time in gardening (2 vs 1.5 h·wk<sup>-1</sup>) and do-it-yourself work (1.5 vs. 0.5 h·wk<sup>-1</sup>),

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and less time on housework than the women (1.5 vs. 4.5 h·wk<sup>-1</sup>) (Bak et al., 2005).

In the Karelia study from Eastern Finland, 1704 men and 2182 women aged 45-64 were examined. More men than women reported heavy physical activity at least 3 times per wk, whereas a slightly smaller percentage of men than of women reported walking 4 or more times per week (51.1% vs. 55.3%), or taking no deliberate leisure activity (27.7% vs. 30.1%) (Luotto et al., 1979).

### *North America*

There seem to be some differences in attitudes to leisure between Europe and North America. Aerobics is the most commonly cited leisure pursuit of active American seniors, whereas the German preference is for gymnastics. Moreover, older Americans perceive physical activity mainly in the context of physical fitness, whereas enjoyment is the dominant German motivator (Gambetta and De Pauw, 1995).

A small focus group of low-income U.S. adults aged 55-70 yr found a strong preference for walking in the women, whereas males preferred yard-work to walking (Clark, 1999).

In rural New York, a survey of 1052 men and 1251 women aged >65 yr found that the frequency of "sweat related activity" was 2.5 times per week in men and 2.1 times per week in women. Activities commonly reported by the men and women, respectively, were walking (53.7% vs. 71.0%), gardening (13.5% vs. 8.6%), golf (7.0% vs. 2.6%), cycling (4.0% vs. 5.9%), swimming (1.5% vs. 2.7%), and aerobics (2.1% vs. 3.4%). The men were also more likely to report work-related activity (8.2% vs. 3.4%), including

farming activities and chopping wood (Eaton et al., 1994).

A lifetime questionnaire analysis (DeVera et al., 2010) was completed by a group of 4269 Canadian retirees, 66% of whom had post-secondary education (Ratzlaff et al., 2010). Averaged over their entire lifetime, women reported a greater energy expenditure than the men (126 vs. 107 MET-h·wk<sup>-1</sup>). For the women, this total comprised 70.5 MET-h·wk<sup>-1</sup> of housework, 40.5 MET-h·wk<sup>-1</sup> of occupational activity, and 7.3 MET-h·wk<sup>-1</sup> of sport or recreational activity. The corresponding figures for men were 28.6, 63.9 and 16.9 MET-h·wk<sup>-1</sup>. In those over the age of 65 yr, little occupational activity was reported by either sex. The household duties of women had dropped to around 60 MET-h·wk<sup>-1</sup> for those age 66-70 yr, and in those older than 70 yr household duties were shared relatively equally between men and women.

A second study of 1793 French-Canadians aged 68-82 yr found a similar age-related decline in reported physical activity (from 125.1 to 92.8 units in men, and from 103.1 to 74.9 units in women) between 70 and 80 yr of age (Ávila-Funes et al., 2006). This reduction in habitual physical activity was associated with a deterioration in scores for four tests of functional ability (get up and go, 4 m walking speed, chair stand and balance).

### *Australia*

During a pilot fitness survey, (Booth et al., 1997) asked some 766 Australians aged 60-78 yr their preferred forms of exercise; 68% preferred walking, and 13% swimming, with no major differences between men and women.

However, a self-report survey of Australians living in Melbourne found fewer men than women walking > 60

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min·wk<sup>-1</sup> (43.9% vs. 52.2%). Moreover, walking >60 min·wk<sup>-1</sup> was more common in those aged 65-74 yr than in those aged 25-34 yr (54.4% vs. 43.7%) (Bentley et al., 2010).

### *Brazil*

A Brazilian questionnaire survey based on the International Physical Activity Questionnaire estimated the duration of leisure activity per week as the sum of reported walking time plus twice the reported amount of vigorous exercise (Azevedo et al., 2007). It found more physical activity in men than in women. In the age group 60-69 yr, inactivity was found in 55.1% of men vs. 60.0% of women, and 29.7% vs. 23.9% of the sample attained an activity score >150 arbitrary units. In those >70 yr, the corresponding figures were 51.7% vs. 71.5% inactive, and 31.5% vs. 13.3% with an activity score > 150 units.

### *Summary*

In most parts of the world, elderly people continue to report substantial sex differences in the types of activities performed. Men engage in more outdoor activities, both sport and domestic maintenance, whereas women undertake more indoor activities, particularly light domestic work. These differences may diminish in advanced old age, as one partner in a marriage has to undertake tasks that the other is no longer able to do.

### ***Volume of physical activity***

Information on the respective volumes of physical activity performed by elderly men and women is available from questionnaires, pedometer/accelerometer step counts and DLW data (Table 4). Many of the reports are from

North American, where public health objectives have been stated firstly in terms of minimum total weekly energy expenditures as estimated from questionnaires, then as minutes of moderately vigorous physical activity, and finally as target daily step counts.

### *Japan*

Questionnaire data for Japanese seniors aged 65-99 yr living in the community of Nakanojo suggested rather similar total energy expenditures for men and women, averaging 79.4 and 79.2 MET·h·wk<sup>-1</sup>. However, when compared with the women, the men performed a greater volume of higher intensity activity (21.0 vs. 15.6 MET·h·wk<sup>-1</sup>), and less lower intensity activity (58.4 vs. 63.6 MET·h·wk<sup>-1</sup>) (Yasunaga et al., 2007).

Yearlong pedometer/accelerometer data for a sub-sample of this population (Yasunaga et al., 2008) showed average step counts of 7884 per d (in men) vs. 6145 per d (in women) at age 65-74 and of 7332 per d (in men) vs. 5360 per d (in women) at age 75-83 yr. In terms of step counts, men registered a 28% and greater volume of physical activity than women of equivalent age, and in terms of the duration of exercise, the men developed 36% more activity at an intensity >3 METs and 29% more activity at an intensity <3 METs.

Pedometer data from the Japanese Health and Nutrition Survey were only collected over 6 days, but generally confirmed these trends (Inoue et al., 2011); the men took more steps than women, a 9.2% difference in those aged 60-69 yr and a 29.9% difference in those aged >70 yr.

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**Table 4: Influence of age and sex on weekly volume of physical activity.**

| Author                   | Sample and age   | Method   | Findings  |
|--------------------------|--|--|---|
| Yasunaga et al. (2007)   | 3084 Japanese, 65-99 yr  | Questionnaire for elderly Japanese                   | Total MET-h-wk <sup>-1</sup> 79.4 (M), 79.2 (F); higher intensity 21.0 (M), 15.6 (F); lower intensity 58.4 (M), 63.6 (F)  |
| Yasunaga et al. (2008)   | 41 M, 54 F<br>65-83 yr<br>Japanese   | Pedometer/accelerometer (1 yr 24 h-d <sup>-1</sup> ) | Step count 7884 per d (M) vs 6145 per d (F)<br>Age 65-74 vs. 75-83: 7332 per d vs. 5360 per d;<br>Activity >3 METs 23.2 min-d <sup>-1</sup> (M), 17.0 min-d <sup>-1</sup> (F)<br><3 METs 60.2 min-d <sup>-1</sup> (M), 46.6 min-d <sup>-1</sup> (F) |
| Inoue et al. (2011)      | 144 M, 124 F,<br>60-69 yr<br>53 M, 42 F<br>70+ yr, Japan                               | Pedometer, 6-d record                                | Step counts 7162 (M), 6559 (F) steps-d <sup>-1</sup> (60-69 yr);<br>4948 (M), 3809 (F) steps-d <sup>-1</sup> (70+ yr)   |
| Folsom et al. (1985)     | 108 N, 135 F<br>45-54 yr;<br>53 M, 166 F 65-74 yr,<br>Minneapolis                      | Minnesota Questionnaire                              | Leisure activity 55-64 yr: 449 kJ-d <sup>-1</sup> (M), 374 kJ-d <sup>-1</sup> (F)<br>65-74 yr: 691 kJ-d <sup>-1</sup> (M), 279 kJ-d <sup>-1</sup> (F)   |
| Dannenberg et al. (1989) | 456 M, 464 F<br>50-59 yr<br>101 M, 91 F<br>60-69 yr Framingham MASS                    | Minnesota questionnaire                              | 5.2 (M), 2.4 (F) MJ-wk <sup>-1</sup> (55-64 yr)<br>6.4 (M), 3.0 (F) MJ-wk <sup>-1</sup> (65-74 yr)  |
| Hovell et al. (1989)     | 283 M, 206 F > 50 yr<br>US citizens  | Questionnaire  | Walking 65 min-wk <sup>-1</sup> (M), 75 min-wk <sup>-1</sup> (F);<br>walking longer than those <50 yr M and F   |
| Fonong et al. (1996)     | 169 M, 138 F<br>67 ± 7 yr<br>Baltimore   | Minnesota Questionnaire                              | Leisure activity 1.54 MJ-d <sup>-1</sup> (M), 1.23 MJ-d <sup>-1</sup> (F)<br>(exercise volunteers)  |
| Tager et al. (1998)      | 707 M, 947 F<br>initially aged 60 yr<br>Californian community                          | Reporting of specific activities                     | 0 METS-wk <sup>-1</sup> 4% M, 7% F; <22.5 METS-wk <sup>-1</sup> 19% M, 23%F; <35 METS-wk <sup>-1</sup> 14% M, 20% F;<br>>35 METS-wk <sup>-1</sup> 63% M, 50% F  |
| Caspersen et al. (2000)  | 43,732 M & F<br>>18 yr   | U.S. National Health Interview Survey                | % of inactive people increases with age, more M than F report vigorous activity, esp. in those > 65 yr.<br>Men also report more strengthening activities.   |
| Satariano et al. (2002)  | 884 U.S. adults<br>>65 yr  | Questionnaire  | Women 1.7 times more likely to report inadequate activity than men (i.e. walking <150 min-wk <sup>-1</sup> )  |
| Brown et al. (2005)      | 13,028 M, 18,090 F<br>50-64 yr<br>5369 M, 8059 F<br>65-74 yr, 2971 M,<br>5775 F >75 yr | U.S. Behavioral Risk telephone survey                | Recommended activity 46.4, 49.3, 43.9% (M), 44.1, 41.3, 33.3% (F).<br>Insufficient activity 40.3, 33.5, 33.7% (M), 42.6, 39.9, 36.3% (F)<br>Inactive 13.3, 17.2, 22.4% (M), 13.3, 18.7, 30.5% (F)   |
| Lee (2005)               | 86 M, 190 F US Seniors Centre<br>60-75 yr  | Questionnaire  | Total METS-wk <sup>-1</sup> 20.3 (M), 14.1 (F)<br>Walking 9.2 km-d <sup>-1</sup> in 45 min (M), 6.7 km-d <sup>-1</sup> in 37 min (F)  |

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*Table 4 Continued*

| Author                      | Sample and age   | Method  | Findings  |
|-----------------------------|--|---|---|
| Bertoni et al. (2009)       | 3089 M, 3393 F<br>62 ± 10 yr<br>U.S. adults without prior cardiovascular disease | "Typical week" Questionnaire  | 186 MET-h-wk <sup>-1</sup> (M), 187 MET-h-wk <sup>-1</sup> (F)  |
| Carlson et al. (2010)       | c. 3000 U.S. Adults > 65 yr  | U.S. National Health interview survey                                       | In those >65 yr, 18.6% report themselves as "highly active" and a further 11.6% as "sufficiently active" Over age range 18-75+ yr, 33.0% M, 24.2% F.  |
| Ayotte et al. (2010)        | 116 married couples<br>50-75 yr<br>Boston, Mass.                                 | Paffenbarger, Yale Questionnaires, self-report                              | Energy expenditure 1.14 MJ·d <sup>-1</sup> (M), 1.05 MJ·d <sup>-1</sup> (F)<br>Walking 7.3 min·d <sup>-1</sup> (M), 9.8 min·d <sup>-1</sup> (F) (p<0.04)  |
| Tudor-Locke et al. (2004)   | 76M, 133F<br>48.4 ± 16.3 yr<br>Mesa, AZ  | Pedometer, 7d   | 7182 steps·d <sup>-1</sup> (M), 5210 steps·d <sup>-1</sup> (F);<br>6319 steps·d <sup>-1</sup> (46-64 yr), 3766 steps·d <sup>-1</sup> (65+ yr)   |
| Bennett et al. (2006)       | 170 M, 317 F<br>low-income U.S.<br><25 to >70 yr                                 | Pedometer, >3d  | 5844 steps·d <sup>-1</sup> (M), 5001 steps·d <sup>-1</sup> (F)<br>4617 steps·d <sup>-1</sup> (60-64 yr)<br>4104 steps·d <sup>-1</sup> (65-69 yr)<br>3295 steps·d <sup>-1</sup> (>70 yr)               |
| Wyatt et al. (2005)         | 360 M, 370 F,<br>representative Colorado residents<br>18 – 60+ yr                | Pedometer, 4d   | 7028 steps·d <sup>-1</sup> (M), 6606 steps·d <sup>-1</sup> (F)<br>6557 steps·d <sup>-1</sup> (50-59 yr)<br>5022 steps·d <sup>-1</sup> (>60 yr)  |
| Avila-Funes et al. (2006)   | 845 M, 929 F<br>68-82 yr<br>Sherbrooke, QC                                       | Questionnaire   | Activity Units 68-72 yr: 125.1 (M), 103.1 (F);<br>73-77 yr: 113.5 (M), 88.8 (F);<br>78-82 yr: 92.8 (M), 74.9 (F)  |
| Chen et al. (2006)          | 3671 M, 5583 F<br>Normal weight<br>Canadians 50-65 yr                            | Community Health Survey   | Leisure-time energy expenditure (kJ·kg <sup>-1</sup> per day)<br>7.7 (M), 7.4 (F)   |
| Klein-Geltink et al. (2006) | 130,000 M & F<br>18->65 yr<br>Canada   | Community Health Survey   | People > 65 yr who are inactive (leisure expenditure <6 kJ·kg <sup>-1</sup> per day): 53.1% (M), 68.2% (F)  |
| Colley et al. (2011)        | Adults 18-79 yr<br>Canada  | Canadian Health Measures Survey (Actical accelerometer, >4d of 10h records) | Step counts 7869 (M), 6970 (F) steps·d <sup>-1</sup> (60-69 yr);<br>4948 (M), 3809 (F) steps·d <sup>-1</sup> (>70 yr)   |
| Martin et al. (2008)        | 229 M, 275 F<br>English<br>68 ± 2.5 yr   | Questionnaire   | Total active energy expenditure<br>483 MET-h/month (M),<br>665 MET-h/month (F)  |
| Bélanger et al. (2009)      | 32 M, 28 F 55-64 yr<br>16 M, 12 F > 65 yr  | English Health Survey   | Moderate or vigorous activity<br>1041 (M), 1015 (F) min·wk <sup>-1</sup> (55-64 yr);<br>1019 (M), 832 (F) min·wk <sup>-1</sup> (>65 yr)   |
| Bassey et al. (1988)        | 56 M, 66 F<br>UK, 71-72 yr   | Pedometer, 7d   | 7142 steps·d <sup>-1</sup> (M), 6000 steps·d <sup>-1</sup> (F)  |
| Harris et al. (2009)        | 114 N, 124 F<br>65-80+ yr<br>British general practice                            | Pedometer, Accelerometer, >5-d record                                       | Compared with age 65-69 yr: -704 steps·d <sup>-1</sup> (70-74 yr),<br>-2513 steps·d <sup>-1</sup> (75-79 yr), -3681 steps·d <sup>-1</sup> (80+ yr)<br>Compared with M: -525 steps·d <sup>-1</sup> (F) |



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*Table 4 Continued*

| Author                            | Sample and age  | Method   | Findings   |
|-----------------------------------|---|--|--|
| Sogaard et al. (2000)             | 288 Norwegians<br>67-79 yr  | Norkost Survey   | 65% of M & F active 2 or more times/wk for 20 min (walking, jogging, skiing or swimming)   |
| Schröder et al. (2004)            | 177 M, 191 F<br>55-64 yr,<br>167 M, 150 F,<br>65-74 yr<br>Gerona, Spain | Minnesota questionnaire  | Daily energy expenditure<br>55-64 yr 9.4 MJ·d <sup>-1</sup> (M), 8.6 MJ·d <sup>-1</sup> (F)<br>65-74 yr 8.6 MJ·d <sup>-1</sup> (M), 7.8 MJ·d <sup>-1</sup> (F)   |
| Bertrais et al. (2005)            | 1902 M, 1930 F<br>50-69 yr, France                                      | Questionnaire  | Moderate activity 40.6% (M), 36.2% (F)<br>Vigorous activity 23.9% (M), 15.5% (F)   |
| Elizondo-Armendáriz et al. (2005) | 84 M, 92 F<br>Spanish 55-65 yr  | Paffenbarger questionnaire   | Sedentary: 80.3% (M), 86.3% (F)  |
| Duvigneaud et al. (2008)          | 807 M, 633 F<br>Flemish 48 ± 13 yr                                      | Questionnaire  | Leisure physical activity 14.6 h·wk <sup>-1</sup> (M), 13.5 h·wk <sup>-1</sup> (F)<br>Overall energy expenditure (1 wk average, METS)<br>1.77 (M), 1.66 (F)  |
| Sequiera et al. (1995)            | 265 M, 228 F<br>25-74 yr Swiss  | Pedometer 7d   | 55-64 yr: 9600 steps·d <sup>-1</sup> (M), 8000 steps·d <sup>-1</sup> (F)<br>65-74 yr: 6700 steps·d <sup>-1</sup> (M), 7300 steps·d <sup>-1</sup> (F)   |
| Davis & Fox (2007)                | 70 M, 93 F<br>Europeans aged 76 yr                                      | Actigraph 7d   | Active energy expenditure 1.54 MJ·d <sup>-1</sup> (M), 1.07 MJ·d <sup>-1</sup> (F)<br>Mod. vigorous activity 23.8 min·d <sup>-1</sup> (M), 16.7 min·d <sup>-1</sup> (F)  |
| Black et al. (1996)               | 574 subjects<br>2-95 yr<br>Affluent societies                           | Doubly-labelled water  | Averaged 24 h energy expenditure M vs. F<br>Age 40-84 1.64 vs. 1.69 METS<br>Age 65-74 1.61 vs. 1.62 METS   |
| Simpson et al. (2005)             | 387 adults,<br>4 European regions                                       | Questionnaire  | Hrs activity/wk, M vs. F:<br>N. Ireland 3.6, 2.9 (55-70 yr)<br>Clermont Ferrand 5.4, 4.2 (55-70 yr),<br>Rome 1.9, 1.1 (70-85 yr),<br>Grenoble 4.6, 3.1 (70-87 yr)  |
| Allman-Farinelli et al. (2009)    | 17,650 M,<br>18,139 F<br>20 to >75 yr<br>Australia                      | 4 leisure activity interviews, 1990-2005 (results averaged for purpose of this review) | 499 kJ·d <sup>-1</sup> (62 yr), 505 kJ·d <sup>-1</sup> (67 yr),<br>518 kJ·d <sup>-1</sup> (72 yr) 442 kJ·d <sup>-1</sup> (77 yr) (M);<br>349 kJ·d <sup>-1</sup> (62 yr), 343 kJ·d <sup>-1</sup> (67 yr),<br>313 kJ·d <sup>-1</sup> (72 yr), 249 kJ·d <sup>-1</sup> (77 yr) (F) |
| Azevedo et al. (2007)             | 1344 M, 1756 F<br>20 to >70 yr<br>Pelotas, Brasil                       | Questionnaire  | Weekly activity time (walking + 2 x reported vigorous activity, o, <150 min·wk <sup>-1</sup> , >150 min·wk <sup>-1</sup> )<br>60-69 yr : 55.1, 15.3, 29.7% (M);<br>60.0, 16.1, 23.9% (F)<br>>70 yr: 51.7, 16.9, 31.5% (M),<br>71.5, 15.2, 12.3% (F)                            |
| Aleman-Mateo et al. (2006)        | 40 rural adults >60 yr, Chile, Cuba & Mexico                            | Doubly-labelled water  | Active energy expenditure<br>3.05 MJ·d <sup>-1</sup> (M), 2.26 MJ·d <sup>-1</sup> (F)  |

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### *United States*

With one or two exceptions, questionnaire-based estimates of weekly active energy expenditure have shown the men as reporting more physical activity than the women, although details differ between surveys.

In Minneapolis, levels of daily leisure activity were very low in both sexes (Folsom et al., 1985). At age 55-64 yr, the geometric mean energy expenditure was 449 kJ·d<sup>-1</sup> in men (n = 108), and 374 kJ·d<sup>-1</sup> in women (n = 90), while at 65-74 yr, the corresponding figures were 691 kJ·d<sup>-1</sup> in men (n = 53) and 279 kJ·d<sup>-1</sup> in women (n = 77). The main activities reported in this study were walking, lawn and garden work and home repair. Despite the low total volumes of daily activity, significant correlations were seen with a number of cardiac risk factors, including BMI (both sexes), HDL cholesterol (both sexes) and systolic blood pressure (women only).

Perhaps because subjects were recruited for an exercise study, much higher daily leisure energy expenditures were observed in Maryland, when the same Minnesota questionnaire was applied to a group of 67-yr-olds [1.54 MJ·d<sup>-1</sup> in men (n = 167) and 1.23 MJ·d<sup>-1</sup> in women (n = 138)]. In subjects from this sample, activity levels were unrelated to HDL cholesterol after statistical adjustment for waist circumference and diet (Foning et al., 1996).

Participants in the Framingham follow-up study also completed the Minnesota Leisure-time Physical Activity Questionnaire (Dannenberg et al., 1989). There was some increase of leisure activity with retirement, but average values were much higher in men than in women both before and following ceasing employment.

In a convenience sample of 86 men and 190 women aged 60-75 yr, drawn from U.S. Seniors' Centres, the men reported more leisure activity than the women (respective totals of 20.3 vs 14.1 MET·h·wk<sup>-1</sup>, walking distances of 9.2 vs. 6.7 km·d<sup>-1</sup>, and walking times of 45 vs. 37 min·d<sup>-1</sup>, with similar scores for household activity, and no great inter-individual differences attributable to previous experience of exercise, perceived health, self-efficacy, perceived barriers or motivations to exercise (Lee, 2005).

In contrast with these findings, a survey of San Diego residents aged > 50 yr found a similar duration of "walking for exercise" in men (65 min·wk<sup>-1</sup>) and women (75 min·wk<sup>-1</sup>). Moreover, the duration of walking for both men and women was greater in older than in younger age groups (Hovell et al., 1989).

A small sample of older married couples living on the Atlantic coast of the U.S. found that neither sex undertook much walking. Overall energy expenditures were similar in men and women, but the average daily duration of walking (7.3 vs. 9.8 minutes) was significantly greater in women than in men (Ayotte et al., 2010).

A sample of 707 men and 947 women initially aged 60 yr from Sonoma, CA were questioned about 22 specific activities. Once more, the responses suggested that the men were more active than the women. The sample was divided into four bands of weekly energy expenditure: none (4% of men and 7% of women), <22.5 METs/wk (19% of men and 23% of women), <35 METs/wk (14% of men and 20% of women), and >35 METs/wk (63% of men and 50% of women) (Tager et al., 2004).

A large multi-ethnic sample of adults aged 62 ± 10 yr from North Carolina

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(Bertoni et al., 2009) found that men and women reported a similar total physical activity during a “typical week” (186 vs. 187 MET-h·wk<sup>-1</sup>). Likewise, a randomly selected sample of 133 men and 150 women aged > 60 yr in Buffalo, NY found similar but suspiciously high) daily energy expenditures of 164 and 167 kJ·kg<sup>-1</sup> of body mass in men and women (Dorn et al., 1999).

Several surveys have looked at the extent to which groups of elderly people met minimum public health recommendations on the weekly amount of exercise. Among a representative sample of U.S. adults aged > 65 yr who were recruited for the Health Interview Survey, 18.6% were rated as highly active, and a further 11.6% as “sufficiently active.” The comparison of men and women was only undertaken for the entire sample from 18 yr to old age, but this showed a predominance of men reporting that they were highly active (33.0% of the men vs. 24.2% of the women) (Carlson et al., 2010). A further analysis of the same data confirmed that the men were reporting more vigorous activities than the women; they also undertook more muscle strengthening exercises (Caspersen et al., 2000a). The Behavioral Risk telephone survey had substantially different and suspiciously high figures for the prevalence of adequate physical activity in the U.S. population. At an age of 50-65 yr, the recommended level of weekly activity was reported by 46.4% of men and 44.1% of women; corresponding figures at 65-75 yr of age were 49.3% and 41.3%, and in those aged >75 yr, the figures were 43.9% and 33.3% (Brown et al., 2005). Those from the three age cohorts who reported that they were inactive included 13.3%, 17.2% and 22.4% of the men and 13.3%,

18.7% and 30.5% of the women; the remainder of the sample were classed as insufficiently active (Brown et al., 2005).

The sex differential in habitual physical activity is confirmed by most of the available pedometer data. Seven-day pedometer counts from South Carolina showed average counts of 6319 steps·d<sup>-1</sup> in those aged 46-64 yr, declining sharply to 3766 steps·d<sup>-1</sup> in those aged >65 yr (Tudor-Locke et al., 2004). These average reflected values of 7182 steps·d<sup>-1</sup> for the men, and 5210 steps/d for the women, a larger sex differential than seen in Japan. Findings were somewhat similar in a low-income sample of 487 adults of all ages from Boston, Mass (Bennett et al., 2006). Average pedometer readings for at least 3 days of recording were greater in men (5844 steps·d<sup>-1</sup>) than in women (5001 steps·d<sup>-1</sup>), and declined steeply during the retirement year (4617 steps·d<sup>-1</sup> at age 60-64 yr, 4104 steps·d<sup>-1</sup> at 65-69 yr, and 3295 steps·d<sup>-1</sup> if >70 yr). Three-day pedometer readings for a representative sample of adults from Colorado yielded somewhat higher values than the two preceding surveys (Wyatt et al., 2005), with a much smaller male/female difference (7088 vs. 6606 steps·d<sup>-1</sup>), although again in old age there was a sharp drop-off to lower values than seen elsewhere in the world (an average of 5022 steps·d<sup>-1</sup> in those aged >60 yr).

### *Canada.*

In Canada, the Community Health Survey of 2000-2001 estimated the total daily leisure-time physical activity of normal weight men and women aged 50-65 yr (Chen and Mao, 2006). Values per kg were similar in men and in women (7.7, 7.4 kJ·kg<sup>-1</sup> per day), although because of a larger body mass, the

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absolute values were substantially larger in the men.

The Canadian Health Measures Survey obtained Actical accelerometer data on a representative sample of Canadian adults during the period 2007-2009. Data were considered as valid if recordings had been obtained for 10 or more hours on at least 4 days (Colley et al., 2011). One of the objectives of the Survey was to determine the proportion of subjects who were undertaking the recommended minimum volume of physical activity, and for this purpose accelerometer readings were constrained to a 4 category classification; sedentary (<100 counts/min), light activity (100-1535 counts/min), moderate activity (1535-3962 counts/min) and vigorous activity (>3962 counts/min). The percentage of the population taking "adequate" physical activity decreased from 52.5% to 15.4% if only exercise bouts of >10 min duration were considered, and to 4.8% if considering only bouts >30 min. This is an important issue in the monitoring of the elderly, since many of their bursts of physical activity are of quite brief duration. Among the Canadian men and women aged 60-79 yr, total counts averaged 7869 and 6970 steps·d<sup>-1</sup>, respectively, much as seen in Japan.

### *United Kingdom*

The English Health Survey found similar reported volumes of moderate and vigorous physical activity in men and women aged 55-64, but the volume of such activity diminished substantially in women over the age of 65 yr (Bélanger et al., 2009). A much smaller study from Hertfordshire yielded conflicting results; in a sample of 229 men and 275 women aged 68 ± 2.6 yr, the men reported less

total activity than the women (483 vs. 665 MET-h/month) (Martin et al., 2008).

An early general practitioner-based study of 7-day pedometer scores in seniors aged 71-72 yr found step counts averaging 7142/d in men and 6000/d in women (Basseley et al., 1988). A second study of English adults aged >65 yr used 5-day records from a Yamax pedometer and an accelerometer (Harris et al., 2009); these two instruments gave similar average counts of 6443 steps·d<sup>-1</sup>. Relative to those aged 65-69 yr, there was a progressive decrease of step count with age, scores being 3681 steps·d<sup>-1</sup> lower in those aged >80 yr. The count for women also averaged 525 steps·d<sup>-1</sup> less than in men.

### *Europe*

European studies of older adults have emphasized the importance of regional differences in behaviour. For instance, the percentages of seniors using public transit in Northern Ireland, Clermont Ferrand (France), Rome, and Grenoble (France) were respectively 4%, 18%, 69% and 30%. The corresponding figures for cycling were 13%, 19%, 11% and 24%, and for walking 75%, 82%, 95% and 91%. Typical hours of physical activity per week in the 4 cities studied were 3.6, 5.4, 1.9 and 4.6 in the men, and 2.9, 4.2, 1.1 and 3.1 in the women (Simpson et al., 2005).

A study of 15 European countries examined the proportion of individuals who were "sedentary" (spending less than 10% of their leisure time in activities at an intensity >4 METs. Both in the age range 55-64 yr (n = 2165, 60.5% vs. 61.5%) and in those aged >65 yr (n = 1914, 52.4% vs. 71.3%), a somewhat lower proportion of men than women reported being sedentary (Varo et al.,

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2003). More importantly, the proportion of sedentary individuals was about twice as high in southern European countries such as Portugal as in Northern European countries such as Sweden (Varo et al., 2003).

A questionnaire examined sedentary behaviour in 1902 French men and 1930 women aged 50-69 yr (Bertrais et al., 2005). A greater percentage of men than women reported engaging in both moderate (40.6% vs. 36.2%) and vigorous (23.9% vs. 15.5 %) physical activity. Application of the Paffenbarger questionnaire to a small sample of Spaniards living in the city of Pamplona also found that in the age group 55-65 yr, fewer men than women reported that they were sedentary (80.3% vs. 86.3%) (Elizondo-Armendáriz et al., 2005). The total energy expenditure of a second sample of elderly Spaniards (177 M, and 191 F aged 55-64 yr, and 167 M and 150 F aged 65-74 yr), as estimated from the Minnesota questionnaire, was somewhat greater in men than in women; at age 55-64 yr, averages were 9.4 vs. 8.6 MJ·d<sup>-1</sup>, and at 65-74 yr, 8.6 vs. 7.8 MJ·d<sup>-1</sup> (Schröder et al., 2004).

In contrast, some European surveys have found little sex difference in the volume of activity undertaken by the elderly. In the Flemish sector of Belgium, a study of 807 men aged 48.5 ± 12.6 yr and 633 women aged 47.9 ± 12.5 yr found the men reporting similar amounts of leisure-time physical activity to the women (14.6 vs. 13.5 h·wk<sup>-1</sup>), and the estimated average intensity of daily metabolic activity also showed little sex difference (1.77 vs. 1.66 METs) (Duvigneaud et al., 2008).

A review of several large questionnaire surveys from Norway, mostly conducted during the 1990s, yielded sometimes

conflicting information (Sogaard et al., 2000). In Norway, there was a progressive increase in the percentage of inactive individuals with age, figures in men increasing from around 30% in those aged 50-54 yr to 35% at 70-74 yr, and 84% in those aged >80 yr; the corresponding figures for women were 40%, 58% and 90% (Sogaard et al., 2000).

However, the NorKost survey for 1997 found that among 288 seniors aged 67-79 yr, 65% of both men and women reported engaging in at least 20 minutes of activities such as walking, jogging, skiing or swimming 2 or more times per week (Sogaard et al., 2000).

Step counts were available for one study of the Swiss population. These showed relatively high average counts for those aged 55-64 yr (9600 steps·d<sup>-1</sup>, in men and 8000 steps·d<sup>-1</sup> in women, but in those aged 65-74 yr, the counts for women (7300 steps·d<sup>-1</sup>) actually exceeded those for men (6700 steps·d<sup>-1</sup>) (Sequiera et al., 1995).

### *Australia and New Zealand*

In Australia, four large national cross-sectional household interview surveys were conducted between 1990 and 2005. There was possibly a small secular trend to an increase of physical activity over this period in older men, but no change in older women. Averaging data across the four surveys, the men undertook more physical activity than the women, ratios increasing from 1.43 at a median age of 62 to 1.65 at 67, 1.65 at 72, and 1.78 at age 77 yr (Allman-Farinelli et al., 2009). The men also showed an increased volume of physical activity coinciding with their retirement.

A survey of 910 New Zealanders aged >60 yr reached similar conclusions, with 48.7% reporting no leisure activity, and

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15.6% no physical activity. The odds of being inactive rose with age and were 1.92 times greater for women than for men (Galgali et al., 1998).

### *Doubly-labelled water data*

A DLW study of adults >60 yr living in rural Chile, Cuba and Mexico found active energy expenditures of 3.05 MJ·d<sup>-1</sup> in men, and 2.26 MJ·d<sup>-1</sup> in women, with greater average values in Mexico than in the other two countries that were studied (Alemán-Mateo et al., 2006).

A systematic review of DLW investigations in developed countries found 574 individual published values in subjects aged 2-95 yr. After excluding both athletes and non-ambulant subjects, and adjusting statistically for the effects of age, height and body mass, the female subjects had an 11% lower total daily energy expenditure than the males (Black et al., 1996). However, differences apparently disappeared in older individuals. At age 40-64 yr, the 24 h energy expenditure averaged 1.64 METs in men and 1.69 METs in women, and in those aged 65-74 the corresponding values were 1.61 and 1.62 METs (Black et al., 1996).

### *Summary*

Both questionnaire reports and pedometer/accelerometer data generally point to a greater volume of habitual physical activity in men than in women, and sex differences are usually greater in the oldest subjects evaluated. Average values differ substantially from one region to another, depending on the local culture, with low values for both men and women in many surveys from the United States and southern Europe.

### *Intensity of physical activity*

When classifying the intensity of activity in the elderly, it is important to make due allowance for the decline of maximal aerobic power (Arroll and Beaglehole, 1991; Bouchard and Shephard, 1994). What younger individuals would regard as quite light activity becomes a moderate intensity for seniors at a threshold energy expenditure of around 3.2 METs in men and 2.8 METs in women. In most surveys, moderate and vigorous physical activity are reported more commonly by men than by women (Table 5).

### *Japan*

Questionnaire data on a substantial sample of 3084 Japanese seniors showed that moderate intensity activity was more prevalent in men than in women (21.0 vs. 15.6 MET-h·wk<sup>-1</sup>, (Yasunaga et al., 2007). There was a progressive decrease in the weekly duration of both moderate and light intensity activity with age (at 65-74, 75-84, and 85-99 yr, respective values were for moderate activity: 20.5 vs. 17.6 vs. 7.9 MET-h·wk<sup>-1</sup>; and for light activity, 70.7 vs. 58.0 vs. 26.7 MET-h·wk<sup>-1</sup>).

Setting the dividing line between moderate and light activity at an energy expenditure of 3 METs, pedometer/accelerometer data (Yasunaga et al., 2008) confirmed that the durations of moderate and light physical activity were somewhat greater in men than in women, and both intensities of activity persisted for shorter times in the older age decade (Yasunaga et al., 2008). The Japanese data indicated showed similar amounts of moderate activity to those reported for Canadian subjects (Colley et al., 2011), but the amounts of light activity in the Japanese sample were lower and more plausible, data agreeing moderately well

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with questionnaire data on a much larger sample of subjects from the same community.

### *United States.*

The U.S. National Health Interview Survey of 2002 (Lethbridge-Çejku et al., 2004) classified the frequency of vigorous activity in various age categories. Among 17,809 individuals aged 65-74 yr, the response was “never” among 77.1% of their sample (F>M), “1-2 times/week” in 7.3% (M>F) and “> 3 times /week” in 15.6% (M>F). In 15,252 subjects aged > 75 yr, the corresponding figures were 88.1% (M<F), 3.2% (M>F) and 8.7% (M>F).

Light activity (< 4 METs) was reported by 13.4% of men and 17.5% of women in a survey of 846 men and 1246 women aged 53-97 yr living in Sonoma, CA (Satariano et al., 2002). Participation in two or more vigorous activities (>6 METs) was reported by 24.2% of the men and 19.7% of the women. The likelihood of vigorous activity in the women was greater if they had a spouse (24.3%) than if they were living alone (16.1%) (Satariano et al., 2002).

In a large multi-ethnic sample of elderly adults (aged 62 ± 10 yr) from North Carolina (Bertoni et al., 2009) the amounts of moderate physical activity reported by men and women were similar, but the men claimed to engage in much more vigorous physical activity than the women (an average of 21 vs. 6 MET·h·wk<sup>-1</sup>).

Questionnaire data on 3298 Manhattan residents aged 69.2 ± 10.3 yr again found that more women than men were rated as “inactive” (43.3% vs. 36.5%) and more men than women reported engaging in “moderate” or “vigorous” physical activity (22.9% vs. 17.8%) (Willey et al., 2010).

A comparison of Amish and non-Amish adults aged 50-60 yr, living in Ohio, found that in both groups the males reported more moderate and vigorous physical activity than the women (Katz et al., 2012).

In contrast, sex differences in the reported intensity of physical activity were small among Chinese immigrants to the U.S.; in a sample of 517 people aged 55-75 yr, the percentages reporting “little,” “moderate” and “high” levels of physical activity were 23.9%, 69.5% and 6.6% in men and 28.4%, 65.6% and 5.9% in women, respectively (Parikh et al., 2009).

### *Canada*

One recent analysis of Canadian questionnaire data looked at surveys that were conducted between 1994 and 2007 to determine the numbers of individuals who reported meeting minimum physical activity recommendations. The numbers meeting the guidelines were much smaller in the elderly than in young adults, but in the most recent survey more men (12.7%) than women (7.9%) met recommendations for both moderate and vigorous activity (Bryan and Katzmarzyk, 2009).

An analysis of findings from the Canadian Community Health Survey also found that the proportion of those aged >65 yr who were considered inactive (a reported leisure activity of less than 6 kJ·kg<sup>-1</sup> per day) was lower in men than in women (53.1 vs. 68.2%) (Klein-Geltink et al., 2006).

Colley et al. (2011) reached similar conclusions from instantaneous accelerometer counts (above). Based on their criteria, elderly men performed somewhat more vigorous (>6 METs) and moderate intensity (3-6 METs) activity

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than women, although the total amounts of such activity were small in both sexes, and there was no significant sex difference in the times devoted to light intensity activity (<3 METs).

### *Europe*

A large survey of older British candidates for diabetes screening found higher levels of leisure activity in men than in women, both among those classified as “Whites” (47 vs. 38 MET-h-wk<sup>-1</sup>) and those classified as “South Asians” (28 vs. 21 MET-h-wk<sup>-1</sup>). Similar amounts of walking were reported by “white” men and women (20 MET-h-wk<sup>-1</sup> in both sexes), but among South Asians, men engaged in less walking than women (8 vs. 12 MET-h-wk<sup>-1</sup>) ((Yates et al., 2010). Similar sex differences emerged when participants were classified as having low, moderate or high levels of daily activity; the respective percentages were for “white” males 22.2%, 28.0% and 49.8%, for “white” females 28.0%, 32.2% and 40.4%, for South Asian males, 36.6%, 25.2% and 38.4%, and for South Asian females 40.4%, 28.2% and 31.4%.

Both questionnaire and accelerometer data were obtained for middle-aged Swedes (Ekelund et al., 2006). The personal monitors indicated little difference in the proportions of light, moderate or vigorous activity between men and women. However, the absolute agreement between questionnaire and accelerometer data was poor, with a wide scatter, particularly if the light activity of walking was included in the analysis (Table 5).

Seven-day Actigraph recordings were obtained on 163 “Better Ageing” volunteers in the U.K., France and Italy. The sample had an average age of 76 yr. Active leisure expenditures amounted to

1.54 MJ·d<sup>-1</sup> in the men and 1.07 MJ·d<sup>-1</sup> in the women. Moreover, the men engaged in moderately vigorous activity for an average of 23.8 min·d<sup>-1</sup>, as compared with 16.7 min·d<sup>-1</sup> in the women (Davis and Fox, 2007).

### *Summary*

The total time that elderly individuals allocate to vigorous physical activity seems somewhat greater in Northern Europe than in other parts of the world. Questionnaire data unfortunately show only a limited correspondence with information collected by pedometer or accelerometer. However, the common theme running through most surveys is that men undertake a greater amount of moderate or high intensity activity than women, but that women engage in a similar or even a greater amount of light activity than the men.

### *Athletic competition*

Data on the physiological characteristics of younger athletes provides a measure of the maximal response to physical activity that can be achieved through rigorous selection and training. How far can similar information on the exercise capabilities of elderly men and women be gleaned from a careful examination of the achievements of Masters athletes? And what can be learned about sex differences in factors motivating participation?

In practice, fewer conclusions can be reached than is possible in studies of younger athletes. Selection is much less rigorous for seniors' competitions than in younger age groups. Further, some seniors undertake quite limited preparation for their events, to the extent that their functional fitness as assessed by the American Association of Health,



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Physical Education and Recreation and Dance (AAHPERD) functional fitness test battery is sometimes very similar to that of their age-matched peers (Shaulis et al., 1996).

### *Participation rates*

Since their inception in 1985, Masters athletic competitions consistently have attracted more men than women, as

**Table 5: Sex differences in intensity of habitual physical activity in elderly individuals.**

| Author                             | Subjects   | Methodology  | Findings   |
|------------------------------------|--|--|--|
| Yasunaga et al. (2007)             | 3084 Adults Japan, 65-99 yr  | Questionnaire  | Moderate intensity activity 21.0 (M) vs. 15.6 (F) MET-h-wk <sup>-1</sup><br>Progressive decline with age (65-74 vs. 75-84 vs. 85-89 yr):<br>Moderate 20.5 vs. 17.6 vs. 7.9 MET-h-wk <sup>-1</sup> ;<br>Light 70.7 vs. 58.0 vs. 26.7 MET-h-wk <sup>-1</sup>   |
| Yasunaga et al. (2008)             | 41 M, 54 F<br>65-83 yr   | Pedometer/<br>accelerometer<br>(1 yr 24 h-d <sup>-1</sup> )                            | Moderate activity >3 METs<br>23.2 (M) vs. 17.0 (F) min-d <sup>-1</sup><br>Light activity <3 METs<br>60.2 (M) vs. 46.6 (F) min-d <sup>-1</sup><br>>3 METs 21.5 (65-74 yr) vs. 13.4 (75-85 yr) min-d <sup>-1</sup><br><3 METs 55.0 (65-74 yr) vs. 43.6 (75-85 yr) min-d <sup>-1</sup>  |
| Lethbridge-<br>Çejku et al. (2004) | 17809 65-74 yr,<br>15252 >75 yr<br>US citizens                           | US National Health<br>Interview Survey<br>2002   | Vigorous activity 65-74 yr: Never 77.1% (M<F),<br>1-2/wk 7.3% (M>F), >3/wk 15.6% (M>F);<br>>75 yr: Never 88.1% (M<F), 1-2/wk 3.2% (M>F),<br>>3/wk 8.7% (M>F)   |
| Satariano et al. (2002)            | 846 M, 1246 F<br>53-79 yr<br>California residents                        | Interview, Sonoma,<br>CA   | Less than brisk (<4 MET) 13.4% M, 17.5% F;<br>Brisk (>4 METS) 29.1% M, 29.6% F;<br>Mod. Vigorous (>6 METS) 33.3% M, 33.2% F;<br>2 vigorous activities >6 METS 24.2% M, 19.7% F;<br>in F, vigorous activity if living alone 16.1%<br>vs. 24.3% if living with a spouse  |
| Bertoni et al. (2008)              | 3089 M, 3393 F<br>62 ± 10 yr. U.S. adults<br>without prior CV<br>disease | "Typical week"<br>questionnaire  | Moderate activity<br>75 MET-h-wk <sup>-1</sup> (M), 69 MET-h-wk <sup>-1</sup> (F)<br>Vigorous activity<br>21 MET-h-wk <sup>-1</sup> (M), 6 MET-h-wk <sup>-1</sup> (F)  |
| Parikh et al. (2009)               | 517 Chinese<br>immigrants to New<br>York, 55-75 yr                       | Questionnaire  | Inactive 23.9% (M), 28.4% (F)<br>Moderate activity 69.5% (M), 65.6% (F)<br>Vigorous activity 6.6% (M), 5.9% (F)  |
| Willey et al. (2010)               | 3293 Manhattan<br>residents<br>69.2 ± 10.3 yr                            | Questionnaire  | Inactive 36.5% (M), 43.3% (F)<br>Light activity 40.5% (M), 38.9% (F)<br>Moderate or vigorous activity<br>22.9% (M), 17.8% (F)  |
| Katz et al. (2012)                 | 62 M, 72 F Amish.<br>64 M, 90 F<br>Non-Amish Ohioans<br>(50-60yr)        | Questionnaire  | Amish: Light activity 10.7 (M), 8.2 (F) h-wk <sup>-1</sup> ;<br>Moderate activity 13.9 (M), 8.7 (F) h-wk <sup>-1</sup> ;<br>Vigorous activity 6.0 (M), 2.6 (F) h-wk <sup>-1</sup> .<br>Non-Amish: Light activity 6.7 (M), 6.7 (F) h-wk <sup>-1</sup> ;<br>Moderate activity 8.3 (M), 4.8 (F) h-wk <sup>-1</sup> ;<br>Vigorous activity 4.6 (M), 2.6 (F) h-wk <sup>-1</sup> |
| Bryan &<br>Katzmarzyk (2009)       | Samples of 10,972<br>to 73,633 Canadian<br>adults 18-55 yr               | Questionnaire  | Fewer old people report meeting physical activity<br>guidelines<br>Fewer women than men report meeting guidelines<br>for moderate & vigorous physical activity   |
| Colley et al. (2011)               | Canadian Adults<br>60-79 yr  | Canadian Health<br>Measures Survey<br>(Actual<br>accelerometer, >4d<br>of 10h records) | Vigorous activity 2 (M) vs. 1 (F) min-d <sup>-1</sup><br>Moderate activity 15 (M) vs. 12 (F) min-d <sup>-1</sup><br>Light activity 208 (M) vs. 205 (F) min-d <sup>-1</sup>   |

## Habitual Physical Activity of the Elderly: Important Considerations

Table 5 Continued

| Author                 | Subjects   | Methodology  | Findings   |
|------------------------|--|--|--|
| Yates et al. (2010)    | 5477 British<br>58 ± 10 yr                           | Questionnaire  | “White”: MET-h·wk <sup>-1</sup> Total 47 (M), 37 (F); vigorous 2 (M), 0 (F) moderate 4 (M), 0 (F); walking 20 (M & F).<br>“S. Asian” MET-h·wk <sup>-1</sup> Total 28 (M), 21 (F); vigorous 0 (M & F); moderate 0 (M & F); walking 8 (M), 12 (F).                 |
| Camões et al. (2008)   | 3407 M, 4753 F<br>Portuguese >65 yr                  | National Health Survey   | Vigorous activity 11.2% (M), 5.2% (F)  |
| Ekelund et al. (2006)  | 87 M, 98 F<br>20-69 yr<br>workers in Uppsala, Sweden | International P.A. Questionnaire (last 7 days)<br>Accelerometry (7 days) | Questionnaire (leisure): Light 12.1 (M), 8.6 (F); Moderate 12.1 (M), 20.4 (F); Vigorous 8.6 (M), 3.6 (F) min·d <sup>-1</sup> ;<br>Accelerometer (total, min·d <sup>-1</sup> ):<br>Light 293 (M), 320 (F);<br>Moderate 38 (M), 40 (F); Vigorous 6.9 (M), 6.2 (F). |
| Petersen et al. (2010) | 2320 to 8189 M,<br>2432 to 8502 F<br>Danish adults   | National Health interviews   | Subjects >65 yr 2005<br>Vigorous activity 6.1% (M), 2.3% (F)<br>Moderate activity 27.2% (M), 18.4% (F)<br>Light activity 52.5% (M), 66.5% (F)<br>Sedentary 13.2% (M), 12.9% (F)  |

might be anticipated from data on the respective types, volumes and intensities of physical activity that the two sexes prefer to undertake. In the initial Masters meet of 1985, there were 6300 registered entrants, 4436 men and 1864 women (Kavanagh et al., 1988). Overall, similar proportions of these male and female competitors chose endurance sports such as running, orienteering, swimming, rowing and cycling (61.2% vs. 65.4%) vs. social sports (38.8% vs. 34.6%). However, men showed a slightly greater preference for most of the endurance options, but a substantially lower preference for swimming (respective percentages involved in running 46.0% vs. 38.9%; cycling 24.8% vs. 22.0%; cross-country skiing 10.5% vs. 7.7%; rowing, 9.5% vs. 5.1%; orienteering 2.3% vs. 2.6%, and swimming 29.2% vs. 62.0%).

A survey of Masters athletes covering the period 1985-1992 drew responses from 551 male and 199 female competitors (Shephard et al., 1995). Some categories of Masters competition start in middle rather than old age, and in 1985,

fairly similar numbers of men and women were under 40 yr of age. However, in those aged 60-69 yr, the male/female participation ratio was 4.45, and in those over 70 yr of age, the ratio was 4.40. It remains to be determined how far the much lower sex ratio in younger competitors reflects a secular trend to a growing involvement of women in sport.

### Motivation

Stated motives for participation in the Masters Games have included maintenance of fitness, camaraderie and competition (Cooper, 2007), with social reasons being seen as more important than competition in both men and women (Kavanagh et al., 1988; Tantrum and Hodge, 1993). Nevertheless, males rated competition as of more importance than did the women. On the other hand, the women valued potential improvements in personal appearance, gains in flexibility and group affiliation more than did the men (Gill et al., 1996).

## Habitual Physical Activity of the Elderly: Important Considerations

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### *Performance*

There is quite a strong “relative age” effect among Masters competitors. Because of the age-related decline in performance, those at the younger end of a given age category are the most likely to succeed in any given competition. Moreover, the “relative age effect” is more marked for men than for women, probably because the competitive standards are higher for the men (Medic et al., 2009).

Men lose their “anabolic advantage” during their retirement years. Nevertheless, female performances in most events remains some 20% below those seen in the men. Male competitors have a greater advantage in field jumping, and particularly in weight-lifting events (where female scores are only about 50% of those seen in men) (Baker and Tang, 2010). However, at least a part of the apparent female disadvantage may reflect a lower participation rate, and thus a smaller pool of female competitors (Baker et al., 2003). Training may also be less vigorous in women than in men. A study of the highest ranked sprinters at the European Veterans Athletic Competitions of 2000 found respective training times of  $7.6 \pm 1.2$  h·wk<sup>-1</sup> (M) and  $4.4 \pm 2.0$  h·wk<sup>-1</sup> (F) at age 60-69 yr, and  $9.0 \pm 1.8$  h·wk<sup>-1</sup> (M) and  $2.8 \pm 1.8$  h·wk<sup>-1</sup> (F) at age 70-79 yr (Korhonen et al., 2003). The training volume of older female runners is limited in part by their propensity for injury, although the risk of injury is less of a constraint for the swimmers. Factors selectively favouring the Masters swimming performance of women include the heavy dependence of the sport on technique, and biomechanical advantages of the female such as overall body size, buoyancy, and limb length. In contrast, running and cycling times are

influenced primarily by the individual’s maximal aerobic power, and this is usually substantially smaller in women than in men.

World records for endurance events such as 10 km runs, 1500 m swims, rowing and triathlons, as well as for weight-lifting, generally show a faster age-related deterioration of performance in women than in men (Anron et al., 2004; Foster et al., 2007; Korhonen et al., 2003; Seiler et al., 1998; Tanaka and Seals, 2003; Wright and Perricelli, 2008). The loss of performance is particularly rapid for orienteers; after the age of 45 yr, their decrease in speed was 13% per decade in men and 16% per decade in women, with an acceleration of these losses after the age of 69 yr. Moreover, female orienteers attained only 81% of the male speed at 45 yr, and speeds had dropped to 69% of their male peers by the age of 65 yr (Bird et al., 2001).

An analysis of the Marathon performances achieved by 552,528 individuals offers one exception to these generalizations. This particular analysis focussed on the 50<sup>th</sup> percentiles rather than record performances, and it noted that the race times showed a similar increase from 60 to 80 yr of age in men (260 vs. 290 min) and in women (275 vs. 300 min) (Leyk et al., 2010). Olympic weight-lifting records for 312 men (average age 54.2 yr) and 51 women (average age 43.9 yr) also suggested a steeper decline of both absolute and relative performance in men (age correlations of -0.78 and -0.77) than in women (age correlations of -0.57, -0.59), although this comparison is complicated by the fact that the men were on average 10 yr older than the women (Thé and Ploutz-Snyder, 2003).

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The age-related decline of performance is usually greater and starts earlier for running and cycling than for swimming (Randsell et al., 2009; Tanaka and Seals, 2003). Longitudinal studies suggest little sex difference in the age-related deterioration of distance performance (Donato et al., 2003; Tanaka and Seals, 1997).

There has been much scientific debate as to whether the rate of loss of maximal oxygen intake and peak power is faster or slower in Master's Athletes than in sedentary individuals (Kavanagh et al., 1988; Shephard et al., 1995), with arguments based on the findings in both cross-sectional and longitudinal investigations. Longitudinal analyses, although theoretically preferable, have often been complicated by changes in patterns of training and have covered too short a period of observation to calculate rates of aging accurately. An 8-yr longitudinal study of 86 male and 49 female athletes found losses of aerobic power increasing in the men from 1.8% per year in those initially aged 40-49 yr to 3.7% in those aged >70 yr, and in the women from 0.9% per year in those aged 40-49 yr to 2.4% per year in those aged 60-69 yr, despite the apparent maintenance of training at least to the age of 70 yr (Hawkins et al., 2001).

Cross-sectional data for male and female Masters athletes have confirmed a progressive decrease of maximal oxygen intake, with male and female values averaging 50.4 and 43.3 mL·kg<sup>-1</sup>·min<sup>-1</sup> at age 50-60 yr (n = 34, 21), 43.6 and 38.0 mL·kg<sup>-1</sup>·min<sup>-1</sup> at age 60-70 yr (n = 25, 8) (despite reporting similar volumes of training to those undertaken by the younger cohort), and (in the men only, with a decrease of training relative to younger individuals) values averaging

35.8 mL·kg<sup>-1</sup>·min<sup>-1</sup> in those aged 70 yr or older (n = 10) (Wiswell et al., 2001; Wiswell et al., 2000).

A cross-sectional evaluation of maximal cycle ergometer power output examined 2038 Dutch men and 898 women aged > 40 yr who had engaged in sport for 4 h·wk<sup>-1</sup> over at least 3 months during the previous year. A multiple regression equation showed that at any given age, the height-adjusted peak power output was 65 Watts higher in men than in women, with an average annual loss of power of 1.95 W in the men and 1.57 W in the women (Bovens et al., 1993).

### *Summary*

The findings in Masters athletes follow the pattern that might be anticipated from the age- and sex-related characteristics of physical activity in the overall population of seniors. Participation in sport is more popular in men than in women, and the one area where women are heavily represented is in swimming. Competition continues to be an important motivator for some elderly men, but social contacts offer the main attraction for female participants. In many sports with the exception of swimming, female Masters performance is only about 80% of that seen in men. This reflects not only some physiological disadvantage in the women, but also limited participation and less rigorous training than their male counterparts.

### *Secular trends*

Given the low levels of physical activity found in many surveys, public health agencies have made vigorous attempts to increase the involvement of seniors in exercise programmes over the past 20 yr. However, neither health promotional

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efforts nor changing cultural norms appear to have had any major influence upon population involvement in physical activity.

### *Japan.*

Yamax pedometer data on a nationally representative sample of Japanese subjects (recorded on a “typical” November day) showed a decrease in the daily step count, from 1998-2000 to 2007; the average decrease amounted to 529 steps·d<sup>-1</sup> (-8%) in men and 857 steps·d<sup>-1</sup> (-12%) in women. This change was accompanied by decreases in the percentages of men and women (-5.1 vs.

-5.0%) classed as “active” (i.e. those reaching an age-adjusted count > 10,000 steps·d<sup>-1</sup>), and an increase in the numbers accumulating less than 4000 steps·d<sup>-1</sup> (i.e. very sedentary) (Inoue et al., 2011). However, this unfavourable time trend was more obvious in younger age groups than in those aged >60 yr. In the 2007 survey, the respective pedometer counts for men and women were 7162 and 6599 steps·d<sup>-1</sup> at age 60-69 yr, and 4948 and 3809 steps·d<sup>-1</sup> at age 70-79 yr, these values being much as observed in 1995.

### *United States*

Several surveys in the U.S. have found small but encouraging increases of physical activity in the general population in recent years. In Minnesota, similar (but not identical) questionnaires were completed by large groups of subjects several times from 1957-60 to 1985-7. Over this period, the average reported energy expenditure increased by about 12 kJ·d<sup>-1</sup> per year, for a total gain of about 350 kJ·d<sup>-1</sup> over the two decades. The gain was seen in both men and women at all ages through to 65-74 yr, with the largest changes in white-collar workers. In

particular, men noted substantial increases in heavy leisure activity between surveys conducted in 1957-60 and 1975-75 (Jacobs et al., 1991).

A comparison of data for 1980 and 1990 in probability samples of Minneapolis-St. Paul residents (groups of between 573 and 2171 men and 1781 to 2348 women in their mid-50s) showed some increase in the reported leisure-time physical activity in all categories of participant. There was also a narrowing of the socio-economic gradient, perhaps because of decreasing occupational demands, with increases of leisure activity among male low-income and low-educational groups, and in female low income groups (Iribarren et al., 1997).

The Behavioral Risk Factor Survey found an increased proportion of middle-aged people reporting some walking from 1987 to 2000 (at age 55-64 yr, respective percentages were 35.9% vs. 42.2% in men, and 44.8% vs. 51.4% in women, but in those aged >65 yr, the corresponding values were 44.6% vs. 44.2% in men, and 40.6% vs. 45.4% in women). Nevertheless, many of the people making such claims were only walking once or twice per week, so that the percentage of middle-aged individuals who were walking for at least 30 minutes 3 or more times per week remained unchanged (Simpson et al., 2003).

Subsequent representative surveys in the U.S. have been even less encouraging, with little evidence of changes in habitual activity from 1998 to 2008, and no comment on possible sex differences in trends (Carlson et al., 2010).

### *Canada*

In Canada, several attempts to deduce secular trends in habitual physical activity have been based upon the

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proportions of the population claiming to meet minimum recommended levels of physical activity in successive surveys. The figures suggest a small increase in compliant individuals from 1994 to 2005, but no acceleration of this trend subsequent to Health Canada's release of its Physical Activity Guides (Cameron et al., 2007).

In any event, the data are hard to interpret, since there have been changes in questionnaire methodology over the period of interest (Bruce and Katzmarzyk, 2002). Moreover, the percentages of people who claim to meet health guidelines could be increased by exercise publicity, without any change in actual behaviour, and in support of this concern, the percentage of individuals claiming to be active is greatly in excess of the figures suggested by objective monitors.

### *Europe*

Cross-sectional questionnaire data on the activity patterns reported by a large sample of Norwegians aged 20-70 yr (214,448 men and 206,136 women) are available from 1972 to 2002 (Anderssen et al., 2008). There has been a marked decrease in the number of people engaged in heavy employment over this period, and looking at a combination of reported leisure and occupational activity, the proportion of sedentary individuals has increased (from 7.2% to 13.7% of men and from 2.8% to 10.3% of women). Further, the proportions engaging in a high level of physical activity have decreased (from 5.0% to 2.6% of men, and from 1.2 to 0.7% of women).

However, a review of several studies conducted during the period 1985 to 2000 suggests there has been a slight increase in the proportion of Norwegians

who engage in moderate physical activity during their leisure time (Sogaard et al., 2000).

Likewise, data from the Danish National Health Interview Survey suggest that the percentage of those aged >65 yr who engaged in moderate physical activity increased from 1987 to 2005 (respective values for the two surveys being 20.4% and 27.2% in men, and 11.9% and 18.4% in women, (Peterson et al., 2010).

Comparison of successive UK Health Surveys over the period 1991-2004 shows (as expected) a substantial decline in occupational activity, but in the age groups 50-64 and >65 yr, both sexes have also reported devoting a progressively greater number of minutes per week to sport activities (Stamatakis et al., 2007).

### *Australia*

Cross-sectional analyses of Australian household interview data from 1990 to 2005 suggest that there has been an increase of both walking and moderate physical activity over this period (Merom et al., 2009), although this could be due in part to population aging (Allman-Farinelli et al., 2009).

Analyzing the same data set by cohort, and averaging across 4 age-groups, data for men aged 62-77 yr show a small trend to an increase of leisure activity (479, 485, 500 and 559 kJ·d<sup>-1</sup>) over the 15 yr, but the data for women in this age range show no obvious secular trend (321, 298, 319 and 315 kJ·d<sup>-1</sup>) (Allman-Farinelli et al., 2009).

### *Summary*

Available data on secular changes in habitual physical activity point to an overall decrease in daily energy expenditures, due largely to decreased

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occupational demands. However, several studies from various parts of the world also suggest that there may have been a small compensatory increase in leisure activity, particularly moderate intensity activity, in both sexes.

### **Correlates and determinants of physical activity**

Many reports have considered superficial correlates of physical activity (Bauman et al., 2002) such as season, immediate environmental conditions, attitudes towards physical activity, perceived environmental barriers, perceptions of health and ability, and the short-term disturbances associated with critical life events. However, much less attention has focussed upon the development of a comprehensive psychosocial model of exercise behaviour.

### **Seasonal influences**

Two reviews of seasonal differences in physical activity do not discuss possible sex differences in the elderly (Reilly and Peiser, 2006; Tucker and Gilliland, 2007). A third review sought such information, but found no published discussion of the effects of age and sex upon seasonal differences in physical activity (Shephard, 1985a). Nevertheless, sex differences are likely to occur (Table 6), given the seasonal nature of many sports (more important for men, as they engage in more sport, above), long-term effects of season upon such pursuits as gardening and home maintenance (active occupations for many seniors), and influences of daylight length upon mood state. *Japan*

Our study of elderly residents of Nakanojo, in central Japan, (Togo et al., 2005; Yasunaga et al., 2008) obtained year-long pedometer/accelerometer data

on a substantial sample of men and women aged 65-83 yr. Levels of physical activity as assessed by step counts were lowest in both sexes during the winter months, with slight sex differences in the magnitude of increases seen over the other 3 quarters of the year (women > men), both for those aged 65-74 yr and for those >75 yr.

### *United States*

Seasonal differences in physical activity could be smaller in the United States than in many other countries. Although many American cities are exposed to the rigours of a continental climate, most U.S. citizens now have opportunity to exercise in air-conditioned malls, gymnasiums and other climatized facilities when outdoor conditions are uncomfortable. On the other hand, travel to indoor facilities can be a problem for the elderly during the winter, an issue exacerbated by a general absence of effective public transportation in North America.

Dannenberg et al., (1989) examined the physical activity patterns of Framingham offspring aged 20-69 yr, using a modified Minnesota questionnaire. The reported leisure activity was about twice as great in summer as in winter, with respective estimates of energy expenditures averaging 1.01 vs. 0.54 MJ·d<sup>-1</sup> in men and 0.53 vs. 0.31 MJ·d<sup>-1</sup> in women. During the summer months, men allocated more time to gardening, carpentry, lawn mowing, golf and running than in the winter, whereas the women showed increased participation in gardening, swimming, health club exercises, dancing and cycling (Dannenberg et al., 1989). Respective percentages of the male times that the women reported spending on walking for

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pleasure were 186% in winter and 140% in summer, but in the summer men also spent 161% more time than women pulling a golf cart; the combined walking + golf score for the women was only 119% of that for the men. The only comment on age/sex interactions concerned subjects spending at least 1 h·d<sup>-1</sup> in specific conditioning activity (>31 kJ·min<sup>-1</sup>). The percentage of such individuals was low in both sexes, but this vigorously active group showed no significant age or sex differences in exercise patterns across the four seasons.

A small study of Minnesota adults used a combination of a 4-week physical activity history, a Caltrac accelerometer and a physical activity record. There were large absolute differences in the volumes of activity estimated by these 3 approaches. On all three measures, physical activity tended to be greater in the warmer months (April to September, 30% for the 4-week activity record, 4.5% for the physical activity recall, and 5.5% for the Caltrac accelerometer) than in the winter. However, seasonal differences accounted for only 5-7% of the individual variability in the data (Levin et al., 1999).

Behavioral Risk Survey data for adults living in Michigan found the estimated weekly leisure-time energy expenditure to be 15-20% greater in spring and summer (April – September) than in fall and winter (October – March) (Pivarnik et al., 2003). The winter months were also marked by an increase in the numbers of those reporting no leisure activity. Moreover, in the summer subjects performed their preferred activity (typically walking) for an average of 5 minutes longer than in the winter. However, interactions between age and sex were not examined in this report.

A survey of 593 ostensibly healthy but somewhat obese adults aged 20 to 70 years old (mean 47.6 yr) who were living in Worcester, Mass, applied a 24-hour physical activity recall (2 weekdays and one weekend day) at five quarterly intervals. From the winter nadir to a peak in summer, the total physical activity showed only a small change (29.9 vs. 30.5 MET-h·d<sup>-1</sup>). The largest seasonal fluctuations were seen in middle-aged males (Ma et al., 2008). In those aged 60-70 yr, activity peaked several weeks after the summer Solstice, substantially later than in younger individuals. A further analysis on what seems essentially the same data set looked at mean values and the amplitude of seasonal variations for occupational activity (6.4, 0.2 MET-h·d<sup>-1</sup> in men; 3.4, 0.6 MET-h·d<sup>-1</sup> in women), household activity (4.0, 0.6 MET-h·d<sup>-1</sup> in men; 4.6, 0.7 MET-h·d<sup>-1</sup> in women) and leisure-time activity (1.8, 1.0 MET-h·d<sup>-1</sup> in men; 1.6, 0.9 MET-h·d<sup>-1</sup> in women). Plainly, the most variable source of energy expenditure was leisure-time activity (Matthews et al., 2001). In men, seasonal variation was greater in those over the age of 50 yr. Obese women and the sedentary of both sexes showed less seasonal variation than the remainder of the sample. These various changes were confirmed in those individuals where physical activity was also measured by a uni-axial accelerometer.

One potential method of encouraging physical activity within a community is to promote active commuting; this is particularly likely to have a beneficial influence upon the health of older individuals. Unfortunately, this potential form of physical activity has less practical relevance for most seniors, and it is particularly vulnerable to the seasonal effects of adverse weather. The U.S.



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National Household Travel Survey of 2001 examined a large population

*Canada*

A retrospective questionnaire study

**Table 6: Seasonal variations of physical activity in elderly men and women.**

| Author   | Subjects  | Methodology   | Findings   |
|--|---|---|--|
| Togo et al. (2005)<br><br>Yasunaga et al. (2008) | 41 M, 54 F<br>65-83 yr<br>Japan                                   | Pedometer/accelerometer. worn 24 h·d <sup>-1</sup> for 1 yr   | Step count winter<summer<spring<autumn (M)<br>Winter<summer=spring=autumn (F)<br>Step count and duration of activity <3 METs and > 3 METs all greater M than F.<br>D Highest vs. lowest month:<br>age 65-74 yr ,1087 steps/d (M) 1460 steps/d (F),<br>age 75-83 yr, 1235 (M) vs. 1299 (F)steps/d |
| Dannenberg et al. (1989)                         | 1598 M,<br>1782 F<br>20-69 yr<br>Framingham, Mass.                | Modified Minnesota questionnaire  | Leisure activity about twice as great in summer (July-September) as in winter (January – March):<br>1.01 vs. 0.54 MJ·d <sup>-1</sup> (M), 0.53 vs. 0.31 MJ·d <sup>-1</sup> (F).<br>No comment on age interactions  |
| Levin et al. (1999)                              | 28 M, 49 F<br>37.4 ± 9.7 yr<br>Minneapolis residents              | 4-week history<br>Caltrac accelerometer<br>Physical activity record   | Physical activity tended to be greater in summer months, but season accounted for little of variability on data  |
| Matthews et al. (2001)                           | 300 M, 280 F<br>48.2 ± 12.5 yr (M)<br>47.1 ± 12.0 yr (F)          | Cholesterol study, Worcester, Mass.<br>3 x 5 24-h activity recalls, supplemented by Actilume accelerometer data | Activity greater in summer than winter<br>0.50 MJ·d <sup>-1</sup> (M) 0.9 MJ·d <sup>-1</sup> (F). Seasonal change in men greater if >60 yr. Obese women and sedentary individuals of both sexes show smaller seasonal variation  |
| Ma et al. (2008)                                 | 316 M, 277 F<br>overweight,<br>47.6 ± 12.4 yr<br>Worcester, Mass. | 24 h activity recall  | Increase of activity from winter (Dec 21-Mar 20) to spring (Mar 21-June20) (29.9 vs. 30.5 MET-h·d <sup>-1</sup> );<br>peak amplitude 1.24 MET-h·d <sup>-1</sup> , largest in middle-aged males   |
| Pivarnik et al. (2003)                           | 1208 M,<br>1635 F<br>age 18 - >75 yr<br>Michigan residents        | Behavioral Risk Factor Survey   | Leisure activity 15-20% greater April – September than October – March. No comment on effects of age or sex.   |

sample, including 16,034 men and women aged >65 yr. Even among the elderly, people were taking an average of 0.31 active trips per day, this being most likely if the distance to be covered was <1.6 km. The survey noted that active commuting was greater during the summer (a 36% increase in July) and less during the winter (a nadir of -15% in March), with women showing a larger effect of season than the men (Yang et al., 2011).

based on a large sample of elderly people who were living in Saskatchewan, together with a small number of elderly subjects from two U.S. mid-west cities found that the greatest impact of season was upon activities adversely affected by winter weather, such as golf and gardening. There were increases of gardening, walking and outdoor sports during the warm season, but these were offset by small decreases of dancing and indoor sports. No significant sex

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differences were noted in this study (Mobily et al., 1995).

Questionnaire estimates of recreational walking in Calgary (AL) suggested that this form of leisure activity was more prevalent in the spring (March/April) than in the winter (January/February) (odds ratio of 1.65 for those aged >60 yr, but 1.04 in men and 1.75 in women for subjects of all ages) (McCormack et al., 2010).

### *United Kingdom*

A telephone survey of a large sample of Scottish adults (7202 men and 9284 women aged 18-60 yr) examined the percentages of individuals who reported taking physical activity once and three or more times per week in different months of the year. Seasonal variation was greater among the older subjects (Uitenbroek, 1993). The peak frequency of physical activity occurred later during the season in men than in women (late vs. early July) and peaked later in those aged 46-60 than in those aged 18-25 yr (August vs. June).

### *Holland*

The DLW technique was applied in summer and in winter to a small group of employees at the University of Maastricht, Holland (10 men and 42 women aged 20-60 yr) (Westerterp et al., 2005). The ratio of total energy expenditure to the resting energy expenditure as measured in a metabolic chamber was slightly greater in summer than in winter (1.87 vs. 1.76). Effects of age and sex were not discussed in this report.

### *Summary*

Studies from various countries around the world show seasonal changes in the choice of physical activities by elderly

individuals. Preferences differ between men and women, but in general there is some increase of energy expenditures among elderly subjects of both sexes during the warmer months of summer.

### ***Immediate environmental conditions***

The main aspects of immediate weather conditions that have an adverse influence upon involvement in physical activity are a period of heavy rainfall and extremes of environmental temperature.

Rain can be unpleasant unless a person has adequate protective clothing, and it may preclude certain activities such as mowing the lawn or gardening, typical activities for elderly men.

Many Canadians and others living in cities with continental climates face a winter icing of their streets, likely to deter outdoor walking among elderly women with a weak bone structure. Ice and snow on city streets also discourages driving by older people of both sexes, potentially reducing their visits to indoor sports facilities. In many U.S. cities, summer heat waves are accompanied by warnings that seniors should stay indoors for health reasons, since elderly people have a reduced capacity for thermal regulation.

Bad weather can also be used as an excuse for avoiding involvement in physical activity. People who see weather as a barrier to physical activity are more likely to be inactive (Salmon et al., 2003), and a spell of bad weather is one factor leading to abandonment of an exercise programme (Stetson et al., 2005).

Our empirical pedometer/accelerometer study examined Japanese people aged 65-83 yr who were living in the town of Nakanojo (Togo et al., 2005; Yasunaga et al., 2008). We observed a progressive decrease in physical activity on days with > 1mm of rainfall, the effect

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being substantial when precipitation exceeded 10 mm. Physical activity also tended to decrease as the environmental temperature departed from an optimal value of 17°C, with a steep decline as temperatures dipped to 0°C and a more gradual reduction as temperatures rose to 29°C. However, we saw little evidence of sex differences in these relationships. Differences in hours of sunshine, daylight, wind speed and relative humidity all had little influence on physical activity, once allowance had been made for the effects of rainfall and dry bulb temperature.

In the U.S., a comparison of Behavioral Risk Factor Surveillance System data from 355 counties showed that recommended levels of physical activity were most likely to be observed in areas where the climate was dry, with moderate temperatures (Merrill et al., 2005). Application of a 24-h physical activity recall technique to a sample of 300 men and 280 women from Worcester, Mass (average age 47-48 yr) showed an increase of total physical activity in the summer; this amounted to 1.4 MET-h·d<sup>-1</sup> in men and 1.0 MET-h·d<sup>-1</sup> in women (Matthews et al., 2001). The increase was mainly attributable to moderate intensity leisure activity, which rose by 51 min·d<sup>-1</sup> in men and 16 min·d<sup>-1</sup> in women.

Other investigations of this question have been limited to younger individuals. Adolescents in Montreal showed a 2-4% decline in physical activity on days with > 10 mm of rainfall, and a 1-2% increase of activity for a 10°C rise in environmental temperature, but the authors of this report made no comment on possible sex differences in responses (Bélanger et al., 2009). Among university students in Melbourne Australia, the main deterrent of cycling to class was rain, although the

overall effect of precipitation was small (Nankervis, 1999).

### *Attitudes to physical activity*

One recent systematic review concluded that at present there were too few good quality studies to comment on the psychological determinants of physical activity in healthy older adults (Koenemann et al., 2011). However, the attitudes towards physical activity reported by the average elderly person seem generally similar to those already noted in Masters' competitors (above). Older people generally value physical activity as a means of enhancing social networks and staving off the course of aging (Allender et al., 2006).

A study of 110 Korean immigrants to the U.S, aged 60-89 yr found associations between participation in physical activity and perceived health and self-efficacy, but no sex differences in these relationships (Sohng et al., 2002). Likewise, a small survey of 44 Baltimore Nursing Home residents (average age 88 yr) found that exercise participation was associated with self-efficacy, motivation and balancing ability, again with no sex differences in the findings (Resnick, 1998).

Among a group of 111 men and 83 women aged 50-65 yr enrolled in a Californian exercise programme, the extent of participation was associated with the individual's perceived health, although the women in this sample had poorer perceptions of their health and psychological well-being than did the men (Stewart et al., 1993). A study from South Carolina concluded that when compared with men, women were also more susceptible to normative beliefs and had a stronger motivation to comply at all

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stages in the process of exercise adoption (Troped and Saunders, 1998).

Many of the studies of interactions between attitudes and exercise behaviour have been conducted in Canada. Sidney and his associates used Kenyon's semantic differential inventory to examine attitudes among University faculty and staff aged > 60 yr who had volunteered for a lunch-time exercise programme (Sidney et al., 1983). In their sample, the men valued the aesthetic experience, health and fitness and the release of tension less than female participants.

Godin and Shephard (1985) applied Fishbein's model of Planned Behaviour to a study of the psycho-social factors influencing exercise behaviour in a population of men and women aged 45-74 yr. They made little comment on possible sex differences in the model, although they did note that the intention to exercise was generally stronger for men than for women (Godin and Shephard, 1985). A recent monograph has summarized Godin's ideas on the multiplicity of factors influencing positive health behaviours (Godin 2012).

An Edmonton, AL, study of 107 well-motivated men and 181 women (average age 71.5 yr) provided further support for the relevance of Fishbein's model of Planned Behaviour to the physical activity patterns of the elderly (Courneya, 1995). Control beliefs influenced attitudes and the intention to exercise, and the stage of readiness for exercise were influenced by attitudes, intention and perceived control, with no apparent influence of sex on these various inter-relationships.

Data from a further large sample of 6739 Canadian adults aged  $50 \pm 16$  yr concluded that age and sex had little influence upon the weightings to be used

when constructing a model of Planned Behaviour, with the exception that older individuals had greater perceived control than young adults, probably because the latter faced the competing demands of career and parenthood (Rhodes et al., 2008).

### *Perceived supports and barriers to physical activity*

In Western nations, physical activity usually shows a positive association with education and socio-economic status. A variety of barriers to physical activity are commonly cited, but it remains unclear whether these are real impediments to exercise or simply facile excuses (Table 7).

### *Factors encouraging physical activity*

A study of 69-yr-old U.S. subjects (M = 376, F = 870) divided participants by skin colour and sex (Gallant and Dorn, 2001). In addition to previous involvement in physical activity, predictors of current involvement, as seen in hierarchical regression equations were for "white" men education and health, for "black" men health, for "white" women age, income, health and social support, and for "black" women income, age, health and social integration.

A small focus group explored attitudes towards physical activity in older, low income Americans (11 M, 17 F, aged 55-70 yr). It reported that "willpower" provided the main support for exercise participation among men, but women relied upon encouragement from a group setting and a good leader (Clark, 1999). Data from a further 42 U.S. focus groups found that common enablers of physical activity were positive outcome expectations, social support, and programme access, and that commonly

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reported barriers were health problems, fear of falling, and inconvenience

was a negative factor (Sallis et al., 1992; Sallis et al., 1989).

**Table 7: Perceived supports and barriers to the involvement of elderly men and women in physical activity.**

| Author                                       | Sample and age                                | Sex differences  |
|--|---|--|
| Hovell et al. (1989)<br>Sallis et al. (1989) | 437 M, 301 F<br>San Diego residents<br>>50 yr | Main determinants of walking for exercise self efficacy (M & F) and social support (F)<br>Positive influences: role modelling (M), home exercise equipment (M), good diet (M & F), social support (F).<br>Negative influences age (M & F), barriers (M & F); smoking (M) |
| Clark (1999)                                 | 11 M, 17 F<br>low-income US<br>55-70 yr       | Exercise facilitated by willpower (M), group setting and good leader (F)<br>Perceived barriers: adverse weather (M), lack of money, transport & places to exercise, adverse weather (F)  |
| Haley & Andel (2010)                         | 686 community-dwelling Americans, 60-96 yr    | Men more likely than women to engage in gardening and yard work, walking, sports and exercise  |
| Humpel et al. (2012)                         | 141 N, 145 F inactive Germans<br>72-93 yr     | Perceived barriers: lack of opportunity (16% M, 30% F); lack of transport (7% M, 29% F)  |
| Sjogren et al. (2010)                        | 451M, 548 F<br>Swedes 60-96 yr                | Perceived barriers: cost 12.2% (M), 21.5% (F); fear of violence 2.4% (M), 13.0%; fear of falling 3.3% (M), 10.8% (F); lack of access to countryside 11.1% (M), 18.1% (F)   |
| Booth et al. (1997)                          | about 766 Melbourne adults<br>60-78 yr        | Preferred supports: doctor or health professional (38%, M>F), group exercise (31%, M < F)<br>Perceived barriers: injury (40%, M<F); poor health (27%, M<F); lack of time (20%, M>F); lack of motivation (16%, M>F).  |
| Lim and Taylor (2004)                        | 8881 Australians<br>> 65 yr                   | Men more likely to be active than women<br>Factors associated with lower prevalence of adequate activity (M vs. F): fear of falling (33.4% vs. 54.4%); feeling unsafe (45.0% vs. 49.5%); lack of independent travel (18.6% vs.52.1%); poor health *24.1% vs. 47.9%).     |

(Mathews et al., 2010).

A sense of self-efficacy (in both men and women) and social support (in women) were dominant correlates of walking for exercise in San Diego residents > 50 yr of age (Hovell et al., 1989). Further analysis of the San Diego data set found that in the men exercise involvement was positively associated with role modelling, availability of exercise equipment at home and good dietary choices, and was negatively correlated with perceived barriers (such as a lack of time, lack of equipment and fear of injury), age and cigarette smoking. In women, exercise participation was positively associated with support from a friend and wise dietary choices, while age

A group of 199 older Canadian adults perceived as many as 17 barriers to regular physical activity. The number of impediments that were cited increased with age, but was unrelated to the individual's sex (O'Neill and Reid, 1991),

In Arnhem, Holland, an effect of social status was only observed in men (perhaps because the main component of physical activity reported by the female study participants was housework) (van dem Hombergh et al., 1995). Other factors influencing activity patterns in the Dutch sample were marital status (in elderly women, a living spouse encouraged physical activity) and residence close to shops (a factor increasing the physical activity of men). Disability markedly

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increased the likelihood of being inactive (odds ratios of 7.1 and 28.6 for men and women respectively) (van dem Hombergh et al., 1995).

Hankonen et al. (2010) studied the responses to a fitness intervention in older Finnish subjects (103 men, 282 women) aged 50-65 yr. At baseline, there was no sex difference in self-efficacy, but the men reported that they were receiving more social support than the women. Over the first 3 months of the intervention, the women increased their exercise plans more than the men. Actual increases in physical activity in response to counselling (as shown by questionnaire responses and 7-day activity records) were linked to increases in self-efficacy and planning ability.

Booth and colleagues (1997) asked a substantial sample of elderly Australians who were as yet insufficiently active their preferred sources of support for greater physical activity (Booth et al., 1997). The principal citations were exercise advice from doctors and other health professionals (38%) and the opportunity of exercising as a group (31%). They noted a slight preponderance of men who were seeking professional exercise advice and a slight preponderance of women who wished to exercise as a group.

A study of 177 elderly Singapore residents (average age 62.5 yr) found that the amount of leisure-time physical activity had a positive association with education in men, but a negative association in women (Wong et al., 2003).

### *Perceived barriers*

Perceived barriers have a major influence upon the adoption of physical activity, although objective evidence suggests that the barriers cited are sometimes illusory or excuses for

inaction. In addition to the effects of cold and inclement weather (above), potential barriers to physical activity include the individual's perceived health and his or her personal situation (marriage status, availability of transport, disposable income)(Godin et al., 1994) and physical characteristics of the neighbourhood (safety and walkability). The impact of several of these factors differs between men and women (Humpel et al., 2012).

In the U.S., a sample of 686 community-dwelling adults aged 60-96 yr found that the men were more likely than the women to engage in gardening, yard-work, walking, sports and exercise (Haley and Andel, 2010), with all activities being vulnerable to adverse weather conditions. A study of 2046 free-living subjects aged >55 yr from Sonoma, CA noted that more women (80.0%) than men (73.5%) reported restrictions on their physical activity (Satariano et al., 2000). Medical problems were cited more frequently with increasing age, and women also cited non-medical constraints associated with their living arrangements (living alone or with a spouse was more conducive to exercise than living with others) (Satariano et al., 2002). A focus group study of low-income US adults aged 55-70 yr found men perceiving adverse weather as the main barrier to physical activity, but in women a lack of transport, money and places to exercise were also cited (Clark, 1999). Ayotte et al. examined behavioural pathways among a small sample of U.S. married couples aged 50-75 yr living on the eastern seaboard (Ayotte et al., 2010); they noted significant sex differences in self-regulatory behaviour and outcome expectancies (the latter being more positive in women than in men) Reported health problems had a negative impact

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upon outcome expectations in both men and women, whereas social support increased self-efficacy and self-regulatory behaviour.

Findings from several European studies are generally similar to those reported from North America. In a representative sample of 1784 males and 2373 females ranging in age from 16 to 74 years, the British "*Active for Life*" Survey found an association between the perceived safety of the local environment and physical activity in women, but not in men (Foster et al., 2004). A study of 286 German seniors aged 72-93 yr who did not take enough exercise found that the main reported barriers to greater physical activity were poor health (58%), lack of company (43%) and lack of interest (37%); lack of opportunity (16% vs. 30%) and lack of transport (7% vs. 29%) were cited less frequently by men than by women (Moschny et al., 2011). Among elderly Portuguese living in Porto (55 men aged 77 ± 8 yr and 126 women aged 79 ± 7 yr), the men reported greater leisure activity than the women, and a greater proportion of women cited as barriers concerns about their personal safety and the prevalence of crime in their neighbourhood (Mota et al., 2007). Likewise, Swedish women aged 60-96 yr reported greater constraints on outdoor physical activity than their male peers in terms of costs, difficulty in accessing the open countryside, and fears of violence or falling (Sjögren and Stjernberg, 2010). Limitations of mobility were examined in representative samples of around 5500 Swedish citizens aged 18-75 yr in 1968, 1974, 1981 and 1991, and a further survey of those aged 76-98 yr was undertaken in 1992. Mobility limitations began to affect some of the sample around 40 years of age, with restrictions

reported more commonly by women than by men. The proportion of people reporting mobility limitations at any given age decreased by a third between 1968 and 1991, and the sex difference in these limitations also decreased (for example, the odds ratio that a subject in the 76-98 yr age range would find difficulty in walking a distance of 100 m dropped from around 2.1 to 1.5, probably due to improvements in the general health of this segment of the population)(Ahacic et al., 2000). Nevertheless, even in 1992, less than a half of those over the age of 85 years could walk 100 m or go up and down stairs without difficulty (Ahacic et al., 2000).

The dominant barriers to physical activity perceived by elderly Australians (Booth et al., 1997) were injury (40%, M<F), poor health (27%, M<F), lack of time (20%, M>F) and lack of motivation (16%, M>F). A large survey of Australians over the age of 65 yr found more men than women were likely to report taking an adequate level of physical activity (61.2% vs. 47.2%), with fears of falling (33.4% vs. 54.4%), lack of safety (45.0% vs. 49.5%), lack of independent travel facilities (18.6% vs. 52.1%) and poor health (24.1% vs. 47.9%) all contributing to a lower prevalence of adequate physical activity in women than in men (Lim and Taylor, 2005).

Questioning of a probability sample of 3182 adults aged 20 to >70 yr from Pelotas, Brasil, demonstrated that the absence of a partner was a perceived obstacle to physical activity in women, but not in men (Hallal et al., 2003). A further study of this same population sample noted that all barriers to physical activity were reported more frequently by women than by men. Concerns about

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injury or disease, a dislike of exercise and feeling too old all increased with age, but a lack of time was cited less frequently by the older subjects (Reichert et al., 2007).

### ***Critical life events***

Older adults encounter a growing number of stressful life events, and these can have a negative influence upon their habitual physical activity. Sex-related differences in the influence of such events were evaluated in a sample of 83 men and 101 women aged 65-85 yr from the Japanese town of Nakanojo, using a Japanese language version of the Holmes and Rahe instrument to assess critical life events (Yosiuchi et al., 2010). Study participants noted any of 28 stressful events that they had experienced over the previous year, and rated the stressfulness of each item on a 0-100 scale. The most severe events were death of a partner (in both sexes), and retirement (predominantly in the men). In men, but not in women, the reported number of critical events was negatively correlated with both the daily step count ( $r = -0.27$ ) and the daily duration of activity at an intensity  $>3$  METs ( $r = -0.37$ ). The age-adjusted total severity of events had a significant impact in both sexes, although the effect was again somewhat greater in men (respective correlations for step count and volume of activity  $> 3$  METs  $r = -0.29, -0.37$ ) than in women ( $r = -0.21, -0.25$ ). This difference is supported by the fact that men are more likely to die than women, following the hospitalization of a spouse (Christakis and Allison, 2006).

### ***Summary***

Most studies looking at how meteorological factors modify exercise participation have relied upon questionnaire responses, and often they

have studied broad seasonal bands (for example, summer vs. winter). However, in general the findings match the conclusions drawn from more precise pedometer/accelerometer and DLW data. Surveys from regions with substantially differing climates show a similar optimal temperature for exercise involvement. Outdoor physical activity is generally greater in the summer than in the winter months, and is decreased temporarily by periods of rain. The physical activity of older people shows more seasonal variation than that of younger individuals (Uitenbroek, 1993), but there is less agreement whether seasonal variation is greater in women (McCormack et al., 2010) or in men (Westerterp et al., 2005).

Women are more likely than men to value health, fitness, and the aesthetic experience as outcomes of exercise participation. Formal models of Planned Behaviour seem applicable to exercise adoption by the elderly. Sex differences in the loadings of this model are small for elderly individuals. However, one study found stronger normative beliefs and motivation to comply in women, and another, a stronger intention to exercise in men. Perceived barriers to greater physical activity include a lack of opportunity, lack of transport, lack of a partner and fears about safety of the environment; these constraints all seem to be reported more frequently by women than by men.

### ***Outcomes of physical activity.***

It is generally agreed that the health benefits of moderate physical activity seen in young adults extend also to senior age groups (Shephard, 1997). However, it is less clear whether the benefits are as great as in younger individuals, and fears have sometimes been expressed that



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excessive physical activity might worsen the prognosis of elderly populations. There also remains scope to examine whether elderly men and women show similar responses to habitual physical activity in terms of gains in physical fitness and health.

### ***Fitness levels***

The many factors leading to sex differences in fitness at various ages were reviewed by Shephard (2000). If the volume and intensity of habitual physical activity exceeds a certain threshold, both men and women have the potential to enhance their aerobic function and other measures of fitness such as muscular strength, balance and functional reach. What proportions of elderly men and women reach this training threshold in the course of their habitual activity?

### ***Aerobic fitness***

The association between patterns of habitual physical activity and aerobic fitness was examined in 76 men and 94 women aged 65-84 yr, participants in the Nakanojo study (Aoyagi et al., 2009). Physical activity was determined from year-long pedometer/accelerometer records. As proxy measures of aerobic function, preferred and maximal walking speeds were determined over a 5-m distance. Data showed a progressive increase of walking speeds among those engaged in more habitual activity, to observed maxima of aerobic performance in those taking 13,700 steps/d and spending 62 min·d<sup>-1</sup> in activities at an intensity >3 METs. However, when subjects were divided into activity quartiles, there was no statistically significant increase of maximal walking speed from those in the third quartile (taking an average of 8218 steps/d and

22.0 min·d<sup>-1</sup> at an intensity > 3 METs in the men, and 7030 steps/d, 19.1 min·d<sup>-1</sup> > 3METs in the women) to the values seen for those in the fourth quartile of habitual physical activity. Moreover, the walking speeds reached by subjects in the third activity quartile were already at a level associated with continued functional independence. The coefficients of correlation between pedometer/accelerometer data and walking speeds were similar for men and women, although preferred and maximal speeds of walking were, respectively, 7.2 and 13.5% greater in the men, mirroring the 16.9% difference of step counts seen in the third activity quartiles.

The sex differences in aerobic function that we observed in the Nakanojo population generally mirror those seen in Masters competitors (respective peak aerobic performances in men and women of 14 vs. 12.5 METs, and 223 vs. 189 Watts in those aged 40-49 yr, declining to 8.7 vs. 7.7 METs, and 149 vs. 120 Watts in those > 70 yr (Kavanagh et al., 1988; Kavanagh et al., 1989; Kavanagh and Shephard, 1990; Shephard et al., 1995).

A study of subjects aged 30-80 yr from 7 countries found even smaller sex differences in 6-minute walk distances for the elderly segment of the population; at an age of 60-70 yr, respective distances were 525 m for men vs. 520 m for women, and at 70-80 yr, the distance covered was 470 m in both sexes (Casanova et al., 2011).

One study of 152 men and 146 women aged 55 -86 yr argued that all of the apparent sex differences in maximal oxygen intake could be explained by differences in fat-free mass and habitual physical activity (Amara et al., 2000). However, others have supported our view that there is also an influence of habitual

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physical activity. The age-related decline in maximal oxygen intake in elderly men and women certainly seems to be relatively similar if losses are expressed as a percentage of their respective initial values (Tanaka and Seals, 2003), but if data are expressed as lifestyle-adjusted decreases in peak aerobic power, the loss per decade at 60-70 yr (1.18 vs. 0.89 METs) and at 70-80 yr (1.59 vs. 1.19 METs) is greater in men than in women (Jackson et al., 2009). Losses appear to occur more rapidly in elite athletes than in sedentary individuals, but this is due in part to an age-related decline in training volumes, particularly after the age of 70 yr (Pollock et al., 1997; Shephard et al., 1995; Tanaka et al., 1997; Trappe et al., 1996).

A group of Vermont residents (84 men and 96 women aged 45-90 yr) showed a relatively large sex difference in active energy expenditures as estimated by the DLW method (44%; 3.6 MJ·d<sup>-1</sup> in the men vs. 2.5 MJ·d<sup>-1</sup> in the women), with a correspondingly large difference in peak oxygen intakes (29%; 27 vs. 21 mL·kg<sup>-1</sup>·min<sup>-1</sup>). Significant correlations between active energy expenditure and peak oxygen intake were seen after statistical adjustment of data for age, body fat and fat-free mass, the relationship being closer in men ( $r = 0.42$ ) than in women ( $r = 0.24$ ) (Brochu et al., 1999).

Findings from a larger sample of Americans (378 men and 224 women ranging in age from 18 to 81 yr) confirmed that after adjusting data for fat mass and fat-free mass, a portion of the variance in maximal oxygen intake was attributable to a questionnaire estimate of habitual physical activity in men but not in women. Introduction of habitual activity into a prediction model reduced the annual loss of absolute oxygen

transport (as gauged on the somewhat fallible basis of a linear regression) from 34 to 13 mL·min<sup>-1</sup> in men, but it left the rate of loss in women unchanged at 9 mL·min<sup>-1</sup> (Toth et al., 1994). This appears to support the assumption that physical activity was sufficient to stem the aging of aerobic function in at least some men, but that the lighter habitual activity of the elderly women did not have such an effect.

### *Other fitness variables*

The strength of elderly women is usually much less than that of their male counterparts. An early study of 70-yr-old Swedish city dwellers found that the muscular strength of women was on average only 56% of that seen in men (Aniansson et al., 1980). However, differences in habitual physical activity do not seem to explain all of this large sex difference.

Data from the Nakanojo study showed that knee extension torque was associated with habitual physical activity, particularly in those over the age of 75 yr, with torque measurements apparently approaching a ceiling of benefit among those subjects in the third quartile of physical activity (Aoyagi et al., 2009). The correlation between pedometer/accelerometer score and torque was closer for women than for men, but nevertheless the sex difference in average torque (31.4%) was much larger than the difference in step count for the third activity quartile (16.9%), suggesting that sex differences of maximal torque in elderly individuals were influenced by factors other than habitual physical activity. In this study, handgrip force, body sway and functional reach showed no significant relationships with pedometer/accelerometer data in either

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sex, suggesting that the usual patterns of physical activity did not exercise these functions sufficiently to have any training effect.

A cross-sectional study of 1406 British men and 1444 women averaging 53 yr of age found similar frequencies of reported physical activity in both sexes, but the handgrip force, balance time, and chair rise time were all more closely related to reported physical activity in men than in women (Kuh et al., 2005). A second study examined 229 English men and 275 English women aged  $68 \pm 2.6$  yr; in this older age group, grip strength, 3 m walking speed and chair-rise times were all linked to reports of gardening or participation in "keep fit" programmes in women, but not in men (Martin et al., 2008).

In a sample of older Australians (age  $62 \pm 7$  yr, 481 men and 501 women), the 7-day pedometer count was positively correlated with a dynamometer measurement of leg strength (correlation coefficient 0.86 in men, 0.71 in women) and was negatively correlated with a dual energy x-ray absorptiometry determination of body fat (coefficients of -0.17 in men and -0.39 in women) (Scott et al., 2009).

A study where levels of physical activity (as gauged by both questionnaire and accelerometer data) were matched for Californian subjects aged 32 and 72 yr found a decline of maximal ankle dorsiflexion isometric force in the older vs. the younger men (respective values of 197 N vs. 252 N) but no significant change in the older women (values averaging 148 N vs. 136 N in younger women). This reflects a larger age-related decrease of muscle cross-sectional area in men than in women, with the force per unit of cross-sectional area remaining largely

unchanged with age in either men or women (Kent-Braun and Ng, 1999). A small longitudinal study of isokinetic strength in 52 American men and 68 women with an initial average age of 60 yr showed substantially higher initial strength values in men than in women, but also a faster age-related loss of arm strength in the men than in the women. Over a 10-yr follow-up, cumulative losses of strength amounted, respectively, to: 14.5% vs. 11.8% for the knee extensors; 14.6% vs. 17.4% for the knee flexors; 12.1% vs. 2.4% for the elbow extensors; and 10.2% vs. 2.0% for the elbow flexors (Hughes et al., 2001). However, these losses were not directly related to any decreases in habitual physical activity.

Others have reported a faster decline of muscular strength and power in women than in men (Holloszy and Kohrt, 1995). A 6.5 year follow-up of 707 men and 947 women aged 60 yr in Sonoma CA found that most of the apparent effect of regular physical activity in reducing the likelihood of an impairment in the activities of daily living, both in men and in women, was mediated through an enhanced ratio of lean tissue to body fat (Tager et al., 2004).

### ***Physical and Mental Health***

A wide variety of factors influence beliefs and actions about the interactions between physical activity and health (Godin 2012). Nevertheless, if seniors are to engage in an adequate amount of physical activity, it is probably important that they have some understanding of the impact of such activity upon their physical and mental health.

One year after publication of the 1996 Report of the US Surgeon General, on *Physical Activity and Health*, a telephone survey of 2000 Americans suggested that

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knowledge of the health benefits of physical activity was not greatly affected by the individual's age, but that accurate knowledge of positive responses to exercise was less prevalent in men than in women. Respective percentages of male and female respondents who were aware of the benefits of exercise were for heart disease 82% vs. 86%, for diabetes 46% vs. 52%, for cancer 37% vs. 45%, and most strikingly for osteoporosis 43% vs. 60% (Morrow et al., 1999).

There have as yet been few longitudinal studies of physical activity in relation to health outcomes in the elderly, and available reports on cross-sectional associations between habitual physical activity and health pose the question whether lack of physical activity has caused ill-health, or whether the converse is true. However, a reverse association is not very likely in studies that have used surrogates of the condition in question (such as pulse wave velocity as an indication of arteriosclerosis, or osteosonic index as a measure of the risk of osteoporosis) in subjects who were ostensibly still in good health.

### *Quality of life and mental health*

Tests in a sample of Japanese adults aged 65-85 yr (73 men and 108 women from Nakanajo) demonstrated a significant relationship between pedometer/accelerometer measurements of habitual physical activity and the individual's health-related quality of life (HRQOL) as assessed by the SF-36 questionnaire (Yasunaga et al., 2006). The men had larger overall SF-36 scores than the women, due mainly to higher ratings on the vitality and mental health subscales. The reported HRQOL was lowest for subjects in the lowest quartile of physical activity, but no further gains of

HRQOL were seen on progressing from the second to the third and fourth activity quartiles. Correlations between habitual physical activity (step count or duration of activity > 3 METs) and SF-36 scores were greater in men than in women, but the gains in HRQOL score from the first to the second quartile of physical activity (73.2 or 70.4 vs. 84.0 or 85.0 units in the men, 68.4 or 70.7 vs. 82.6 or 78.4 units in the women) did not show any large sex difference. The findings were susceptible to two possible interpretations; either a very modest level of physical activity enhanced HRQOL, or a poor HRQOL depressed the individual's habitual physical activity. A further study of the same population found that very few of the group had severe depression, but nevertheless, there was a significant inverse correlation between the depression score and habitual physical activity (Yosiuchi et al., 2006).

Another study of 5107 rural Japanese (average age 54 yr) divided subjects into three categories, based on reported active energy expenditures (0, 0-4.2 MJ·wk<sup>-1</sup>, and > 4.2 MJ·wk<sup>-1</sup>) (Morimoto et al., 2006). Men were under-represented in the highest category of physical activity (40 vs. 60%). Moreover, scores were higher on all dimensions of a HRQOL questionnaire among the more active women, who also reported fewer sick-days and fewer incidents of hospitalization (Morimoto et al., 2006). However, men did not show activity-related differences of HRQOL.

Others have reported similar relationships between HRQOL and activity among older individuals in the U.S. and Britain, using a variety of questionnaires (Caspersen et al., 2000b; DiPietro, 2001) (Wareham et al., 2002).

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In summary, quite low levels of physical activity are associated with better HRQOL and mental health, but there remains a need to determine the directionality of this relationship.

### *Absence of physical disability*

The threshold of maximal aerobic power required for continued independent living is probably about 15-18 mL·kg<sup>-1</sup>·min<sup>-1</sup> (Paterson et al., 1999). The age when aerobic power drops below this threshold depends on both the individual's initial fitness level and the subsequent loss of oxygen transport with aging; men generally enter old age with a higher aerobic power than women, but they also show a more rapid loss of maximal oxygen transport as they age. A 10-yr follow-up of 62 men and women through to an average age of 72 yr showed respective final values of 22.0 and 20.2 mL·kg<sup>-1</sup>·min<sup>-1</sup>. Changes over the 10 yr of observation were unrelated to individual physical activity scores, although it is possible that those included in the study were self-selected in terms of their continued absence of disability (Stathokostas et al., 2004).

Other cross-sectional (Wilson and Tanaka, 2000) and longitudinal (Fleg et al., 2005; Hollenberg et al., 2006) studies, also, have failed to find an association between the age-related loss of maximal oxygen intake and habitual physical activity. One explanation of this surprising finding could be that the activity levels reached by most elderly people are insufficient to conserve aerobic power.

Nevertheless, some investigators have argued that a person's habitual physical activity has a substantial impact upon the age at which physical disability develops. A 5.5 yr follow-up of 3495 men and 1175

women aged >40 yr, all clients of the up-scale Cooper Fitness Clinic in Dallas, found 7.5% of the sample reporting one or more functional limitations at follow-up. After controlling for age and other obvious risk factors, the odds of developing functional limitation were reduced in relation to the individual's initial aerobic fitness, as assessed from treadmill endurance times. In men, the odds ratios were 0.4 for those with moderate initial fitness and 0.3 for those with a high level of fitness, and in women the corresponding odds were fairly similar, at 0.5 and 0.3 (Huang et al., 1998). A trend was also noted for benefit from regular physical activity, but the effect was less dramatic, perhaps because the questionnaire estimate of habitual activity lacked precision.

In another 10-yr follow-up of 1097 U.S. subjects aged >65, the factors associated with remaining disability-free until death in a multivariate model included age at death, sex (odds ratio for men versus women 1.72), physical activity (for those who were highly active, an odds ratio 2.04) and a good health record at baseline (Leveille et al., 1999).

Ferrucci et al. followed up 8604 Americans aged > 65 yr who were initially free of disability. A three-level classification of habitual physical activity derived from a simple questionnaire established that the more active individuals not only lived longer, but they also had a longer disability-free life than their more sedentary peers. For reports of moderate and vigorous activity, the respective additional disability-free periods amounted to 3.3 and 5.1 yr in men, and 3.5 and 5.7 yr in women (Ferrucci et al., 1999). A further study of this same population (Leveille et al., 1999) underlined that physical activity

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was a key predictor of the likelihood of remaining free of disability in the year prior to death. In men surviving to >80 yr, the respective probability ratios for men with low and high levels of activity were 15% and 37%, and for women > 85 yr the corresponding figures were 10% and 29%.

A longitudinal comparison between older U.S. runners (452 males, 86 females initially aged 50-72 yr) and North Californian controls suggested that the health advantage over controls in terms of avoiding subsequent disability was large in both sexes, but was greater in female than in male contestants (Chakravarty et al., 2008).

It appears that in order to be effective in preventing disability and dependence, physical activity must be sufficiently vigorous to have a training effect. In their longitudinal study of an elderly population, (Paterson et al., 2004) noted that ordinary leisure activity was unrelated to the onset of dependence, and (Hirvensalo et al., 2000) also commented that the habitual activity of their elderly population did not influence either their likelihood of dependence or death 8 yr later.

In contrast, a meta-analysis showed benefit from moderate to vigorous activity (Tak et al., 2013). A routine exercise programme halved the risk of future disability (Wu et al., 1999). Likewise, the risk of functional decline in a cohort of subjects initially aged 70-74 yr was a third lower in those who were taking regular exercise or walking at least 1.6 km once per week, with similar benefits being observed in men and women (Mor et al., 1989). Six-yr prospective data from the U.S. Cardiovascular Health Study compared questionnaire estimates of habitual

physical activity with reported yr of healthy life; in this study, gains in survival and healthy lifespan associated with exercise were largest in those aged >75 yr, where the most active group demonstrated a substantially longer healthy life: in men, the advantage was 1.49 (95% CI, 0.79-2.19) yr, and in women it was 1.06 (95% CI 0.44-1.68) yr (Hirsch et al., 2010).

In summary, habitual physical activity can extend disability-free yr, but only if the activity is vigorous enough to have a training effect. Women have more potential to benefit from an increase of physical activity than men, because their initial fitness is closer to the disability threshold. However, they are also less likely to take the moderate and vigorous activity needed to maintain oxygen transport and thus avoid the onset of disability.

### *Overall mortality*

The impact of habitual physical activity upon overall mortality arises largely through reductions in the risks of cardiovascular disease and cancer. Comparisons between the sexes are often difficult, since the questionnaires used to assess physical activity patterns were developed for men, and under-estimate the activities undertaken by women. Physical activity might be thought to do more to reduce the incidence of cardiovascular disease in men than in women, in part because of relative disease prevalence, and in part because elderly men are more prone to engage in the moderate and vigorous activity that is needed to counter cardiovascular disease. However, one review of available evidence concluded that, at least for comparable leisure energy expenditures, benefit was as great in women as in men

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(Oguma et al., 2000). In contrast, breast cancer accounts for a substantial fraction of the cancer mortality that is susceptible to physical activity, so that an active lifestyle may do more to reduce cancer mortality in women than in men. Because of these opposing influences, the effect of physical activity upon the overall mortality of the elderly shows little sex differential.

A three-level categorization of leisure activity was undertaken in 302 American seniors aged 70-82 yr, using the DLW method (Manini et al., 2009). Over the following 6 yr, all-cause mortality showed substantial gradients between the most and the least active groups, a 3.32-fold difference in men and a 2.48-fold difference in women.

A 4-yr longitudinal study of 2222 U.S. men and 3679 women aged >70 yr (Rakowski and Mor, 1992) obtained differing estimates of the response to physical activity, depending upon the questions that were analyzed. The odds of death associated with the perception of taking less exercise than one's peers were stronger in men than in women (respective ratios of 1.77 and 1.30). On the other hand, the odds associated with walking 1.6 km less often than once a week were weaker in men (1.15-1.23, ns) than in women (2.49).

The risk of death was also classified by physical activity quartile in a 10-yr follow-up of Framingham Study participants aged >75 yr (96 men and 189 women). However, this information is not easy to evaluate, since data were adjusted statistically for cardiac risk factors, chronic obstructive lung disease and cancer. The women showed a highly significant trend, with a risk ratio of 0.43 favouring top over bottom activity quartiles. The men showed a similar

trend (a risk ratio of 0.67), but in their case the gradient was not statistically significant (Sherman et al., 1994). A 16-yr follow-up of participants in the Framingham study who were initially aged >60 yr compared risks between the most active and the least active tertiles (Sherman et al., 1999). In this analysis, little sex difference was seen. In men (n = 962), the multivariate relative risks for the most active versus the least active tertiles were 0.85 for all-cause deaths, and 0.85 for cardiovascular deaths. For women (n = 1410), the corresponding relative risks were 0.84 and 0.94. Mensink et al., (1996) also found little sex difference of protection against all-cause mortality in a sample of 7689 German men and women aged 25-69 yr who were involved in a cardiovascular risk study. After adjusting data for age, systolic blood pressure, cholesterol level and smoking habits, the odds ratio for all-cause mortality among those who were involved in >2 hours of sport per week relative to those not involved in sports was 0.36 for men and 0.28 for women (Mensink et al., 1996). In the men, there were also sufficient cardiac events to calculate a stable odds ratio of 0.26 for cardiovascular deaths, but this was not possible for the women, since they had few cardiac emergencies.

In Finland, 22,528 men and 24,684 women initially aged 25 to 64 yr were followed for an average of 17.7 yr. Again, those who were active and had a normal body mass index had a substantially reduced odds of overall death, cardiovascular death and cancer-related death, but there were no consistent sex differences in these relationships (Hu et al., 2005).

A longitudinal questionnaire study of Copenhagen residents (381 men and 503

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women aged 65-79 yr) assessed leisure-time physical activity in 1976-78 and 1981-83 (Schnor et al., 2003). Here, the benefit from physical activity was somewhat greater for the men than for the women. Relative to those whose physical activity remained low, those increasing their activity to moderate or vigorous had a reduced risk of all-cause death (a risk ratio of 0.46 for men and 0.67 for women). Those whose activity was initially moderate also had a reduced risk relative to sedentary individuals, provided that this level of activity was maintained (a risk ratio of 0.53 for men, and 0.67 for women), and some continuing benefit was seen even if those who were initially active had allowed their activity to become low at follow-up (a risk ratio of 0.63 in men, and 0.82 in women).

A meta-analysis of questionnaire data from studies where 3 or 4 levels of leisure activity were distinguished in general found only minor sex differences. The exception was of reports of vigorous activity in a 4-level classification. Vigorous activity was not commonly reported by women, but in studies where this was the case, the respective relative risks of all-cause mortality were 0.61 in men and 0.47 in women (Löllgen et al., 2009).

In summary, moderate or vigorous physical activity is associated with a decreased risk of all-cause mortality. Because of opposing relative impacts on cardiovascular and cancer mortality, there is generally little sex difference in overall response in those who reach comparable levels of physical activity. However, elderly women seem less likely to engage in the vigorous bouts of activity needed for maximal protection against premature death.

### *Metabolic risk factors*

Regular moderate physical activity seems sufficient to reduce the risk of developing the metabolic syndrome in both older men (Laaksonen et al., 2002) and older women (Ryan et al., 1996). Some studies have reported physical activity as having more impact on risk factors in men, and others have found a greater response in women, but there seems no consistent sex-linked differences in response.

Accurate assessments of habitual physical activity were made in a Japanese sample of 91 men and 129 women, aged 65-84 yr, using 1-yr pedometer/accelerometer records (Park et al., 2008). Presence of the metabolic syndrome was defined by development of at least 3 of the following adverse (but relatively conservative) markers: a body mass index  $>25 \text{ kg}\cdot\text{m}^{-2}$ , a fasting serum triglyceride level  $>1.7 \text{ mmol}\cdot\text{L}^{-1}$ , a fasting HDL cholesterol  $<1.0 \text{ mmol}\cdot\text{L}^{-1}$  in men and  $<1.3 \text{ mmol}\cdot\text{L}^{-1}$  in women, a systolic blood pressure  $>130 \text{ mmHg}$  and/or a diastolic pressure  $>85 \text{ mmHg}$ , and a fasting plasma glucose  $>6.1 \text{ mmol}\cdot\text{L}^{-1}$  and/or a haemoglobin A1c  $> 5.5\%$ . Development of the metabolic syndrome as thus defined was associated with a low level of habitual physical activity, but since data were adjusted statistically for sex, it was not possible to discern possible differences in this association between men and women.

A cross-sectional survey of U.S. Medicare enrollees aged  $>65$  yr (2070 men, 2730 women) found a 25% difference of reported daily energy expenditure between the most active and the least active quartiles of male subjects, and a 32% difference in the females. In both sexes, the correlation of current body mass with energy expenditures



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showed a relationship of similar statistical significance ( $p < 0.01$ ) (Harris et al., 1997).

The Five Cities study in California examined 235 men and 281 women aged 50-74 yr (Sallis et al., 1986). Those subjects who reported at least occasional participation in 3-5 types of moderate activity were compared cross-sectionally with individuals who reported no physical activities. In the women (but not in the men) greater physical activity was associated with a 4% advantage in terms of body mass index and diastolic blood pressure. Over a 10-yr follow-up of the same population, an increase in composite physical activity score was associated with a small trend to an increase of HDL cholesterol in both men and women ( $r = 0.14$  for each group) (Young et al., 1993). There were also significant effects upon BMI and 10-yr risk of cardiovascular disease in men, but not in women.

A study of 2239 men and 2962 women aged > 65 yr who were enrolled in a Vermont Cardiovascular Health Study noted an inverse association between the quartiles of reported leisure-time physical activity (Minnesota questionnaire) and markers of inflammation, with gradients of 19% for C-reactive protein, 6% for white cell counts, 4% for fibrinogen levels and 3% for Factor VIII activity (Geffken et al., 2001). Data were adjusted for sex, but no comment was made on possible sex differences in these relationship. Habitual exercise also showed positive associations with the risks of diabetes mellitus, hypertension and cardiovascular disease, and here there was no evidence of any effect of sex (Geffken et al., 2001).

An analysis of Canada Fitness data examined the prevalence of self-reported

diabetes in those aged >65 yr, with participants classed as inactive if the questionnaire estimate of their daily energy expenditure was less than 8.2  $\text{kJ}\cdot\text{kg}^{-1}$ . The respective diabetes prevalence rates for active and inactive individuals were 8.2% and 15.3% in men, and 6.5% and 10.0% in women (Choi and Shi, 2001). This small apparent sex difference is at variance with the reports from the U.S., and it remains to be confirmed.

The Allied-Dunbar study in the UK included 246 men and 354 women aged >65 yr (Nevill et al., 1997). It examined the blood pressures of those who had engaged in vigorous physical activity at least once in the previous month. At the age of 25 yr, the benefit from regular exercise was negligible, but at the age of 70 yr the active individuals showed a similar advantage in men (systolic pressure -4.3%, diastolic pressure -3.7%) and in women (systolic pressure -3.3%, diastolic pressure -3.7%).

A German study of 4924 men and 5885 women aged 50-69 yr found that the odds of multiple cardiac risk factors were lower among those performing >3.5  $\text{h}\cdot\text{wk}^{-1}$  of moderate physical activity, both for men (an odds ratio of 0.55) and for women (an odds ratio of 0.44). Lower levels of physical activity of 3.0-4.5 MET-hr or more per week (still at least moderately vigorous, given the age of the subjects) were also associated with lower diastolic blood pressures in women and a lower body mass index in both sexes (Mensink et al., 1999). A further analysis of this same data set (Mensink et al., 1996) showed that the benefit in terms of reduced all-cause and cardiovascular mortality was linked most closely to reported sports participation.

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Associations with conditioning and other forms of leisure activity were weaker.

In summary, indicators of metabolic risk are less prevalent in older individuals who engage in moderate or vigorous physical activity; the advantage for any given level of energy expenditure is relatively similar in men and women.

### *Cardiovascular Health*

Much of the research on physical activity and health has focussed upon the potential of regular exercise to reduce the prevalence of cardiovascular disease, particularly the incidence of myocardial infarction and cardiac deaths. However, to date, there has been greater interest in the impact of habitual physical activity upon prognosis in middle-aged individuals (particularly men) than in responses of the elderly population. Some studies have examined physical activity in relation to markers of vascular atherosclerosis such as pulse-wave velocities or peripheral blood pressure gradients. Others have examined the incidence of specific cardiac diagnoses; the disadvantage of the latter approach is that a long follow-up is required to order in order to accumulate an adequate number of cases.

A systematic review suggests that in women, coronary disease occurs mainly in those over the age of 60 yr; by the 8<sup>th</sup> decade of life, the incidence of this condition is similar in men and women, and physical activity is important as a protective measure in both sexes (Blum and Blum, 2009) (Oguma and Shinoda-Tagawa, 2004). The lower cardiovascular risk in women from younger age groups is due in part to lower levels of several major risk factors.

Although regular exercise *reduces* the risk of heart disease, it does not afford

total protection against cardiac problems. Thus, examination of electrocardiograms from participants in the first (1985) Masters competition demonstrated a clinically significant ST segmental depression of >0.2 mV in 16.2% of male contestants and a rather similar figure of 20.2% for female athletes (Shephard et al., 1995).

A relationship between ultrasonic determinations of arterial stiffness and pedometer/accelerometer measurements of habitual physical activity was demonstrated in a cross-sectional survey of 80 men and 109 women aged 65-84 yr who were living in central Japan (Aoyagi et al., 2010). The central pulse wave velocity was greater in men than in women, implying that the men had greater stiffening of the central arteries. After statistical adjustments for age, sex, and mean arterial pressure, the overall and central vascular stiffness (but not the peripheral vascular stiffness) showed weak but negative correlations with both the individual's daily step count and the daily duration of physical activity at an intensity >3 METs. However, the scatter of data was considerable, and this report made no comment on possible sex differences in response.

Several other authors have found associations between physical activity and central rather than peripheral arterial stiffness. Matsuda et al. studied 413 Japanese men and women aged 45-85 yr; they noted an association between habitual physical activity and central but not peripheral arterial stiffness (Matsuda, 2006), with benefit maximizing at a daily leisure energy expenditure of 0.8-1.2 MJ. Again, no comment was made on any possible sex differences in this relationship.

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A further study, based upon 151 American men aged 18 to 77 yr, found that central arterial stiffness was lower in endurance-trained (vigorously active 5 or more times per week) than in sedentary or recreationally active individuals (Tanaka et al., 2000). The same investigators also studied a group of 53 women, with essentially similar findings (Tanaka et al., 1998); in this sample, central but not peripheral arterial stiffness increased with age, but those who were Masters competitors and highly active avoided atherosclerotic change.

A cross-sectional study of 10,644 U.S. citizens aged 45-64 yr found that after co-varying for other factors, there was only a very weak relationship between B-mode ultrasound estimates of carotid arterial distensibility and reports of participation in vigorous sports activity (Schmitz et al., 2001), with no sex-related differences in any benefit.

In contrast, a substantial Norwegian study used ultra-sound to assess the carotid intimal thickness in 2984 men and 3373 women of average age 61 yr. Reports of taking no physical activity were linked to increased thickness of the vessel wall in men but not in women. Unfortunately, data for those classed as active were not analyzed to explore whether more frequent and/or more vigorous physical activity explained the advantage of the men (Stensland-Bugge et al., 2001).

Other studies have examined only male or female subjects. Kakiyama et al. measured the aortic pulse wave velocity in 149 men aged 19-67 yr (Kakiyama et al., 1998). Aortic stiffness was less marked in those classified as active (an estimated leisure energy expenditure of 6 MJ·wk<sup>-1</sup> on a 7-day activity recall) than in those classed as sedentary (an energy

expenditure <6 MJ·wk<sup>-1</sup>). Yamada et al. (Yamada et al., 2006) examined 149 women with an average age of 54 yr. Their measure of physical activity was relatively weak (the physical functioning scale of the SF-36 questionnaire), but nevertheless they reported that habitual activity showed a weak correlation with peripheral but not central arterial stiffness.

A sample of 809 men and 782 women in Edinburgh, aged 55-74 yr, were asked to recall their level of physical activity when aged 35-45 yr. In men, the reported level of activity had a favourable association with the ankle-brachial pressure index of arteriosclerosis in subjects who were cigarette smokers, and in the women, a history of previous physical activity had a weak positive association with HDL cholesterol (Housley et al., 1993).

In terms of cardiovascular mortality, there is some evidence that exercise offers less protection in men than in women. A longitudinal comparison of aging U.S. runners (452 males and 86 females initially aged 50-72 yr) with North Californian controls suggested a substantial advantage to the athletes over the 21-yr follow-up, but in a multivariate analysis death was also more likely in the men than in the women (Chakravarty et al., 2008).

A Finnish survey followed 47,480 subjects initially aged 25-65 yr over an average of 18.9 yr (Hua et al., 2007). The hazard ratios for cardiovascular events showed a less striking relationship to leisure-time physical activity in men than in women (respective ratios for reports of moderate activity, 0.95 in men vs. 0.85 in women, and for vigorous activity ratios of 0.84 in men vs. 0.77 in women). The women (but not the men) also showed

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fewer cardiac events among those who engaged in active commuting,

A 10-yr prospective study of between 731 and 891 men and 796 to 973 women initially aged 35 to 63 yr found that in men, the risks of coronary heart disease and hypertension were related to the amount of physical activity reported, but in women (perhaps because their overall levels of physical activity were lower), the only association was with the risk of developing diabetes mellitus (Haapanen et al., 1997).

A 7.2-yr follow-up of 6270 men and 8296 women initially aged 45-64 yr found that arm exercise and/or heavy lifting had a protective effect against ischaemic stroke in women (hazard ratio 0.72) but not in men (0.93) (Evenson et al., 1999).

In summary, moderate or vigorous physical activity is associated with both evidence of less central atherosclerosis and a reduced risk of cardiovascular incidents such as myocardial infarction, stroke and cardiac death in elderly subjects. There is little sex difference in objective evidence of central atherosclerosis. In some reports based on clinical end-points, women appear to benefit more than men, but in other studies the reverse is true; this probably reflects differences in the willingness of the elderly women concerned to engage in moderate or vigorous exercise.

### *Sarcopenia*

Habitual physical activity, as measured by a pedometer/accelerometer, is associated with some protection against sarcopenia. A DEXA study of 78 men and 97 women from Nakanajo, aged 65-84 yr, found a lower appendicular muscle mass in the women than in the men (Park et al., 2010). It demonstrated a significant association between this appendicular muscle mass and the daily duration of

activity at an intensity >3 METs ( $r = 0.28$  in men,  $r = 0.38$  in women) (Park et al., 2010). There was also a significant association between muscle mass and daily step count for the women ( $r = 0.36$ ) but not for the men.

### *Osteoporosis*

Bone density and its correlates such as standing height, spinal deformity and the risk of fractures are further variables that show a positive association with habitual physical activity in elderly subjects. Physical activity seems of more benefit to women than to men, probably because the former enter old age with a substantially lower bone density.

In the Nakanajo study, the osteosonic index for the calcaneum was correlated with pedometer/accelerometer measures of habitual physical activity in 76 men and 96 women aged 65-83 yr (Park et al., 2007). On average, the osteosonic index of the women was only 89% of that seen in the men. Associations with habitual physical activity were found in both sexes, but age and body-mass adjusted relationships to both step count and duration of activity at an intensity >3 METs were weaker for the men ( $r = 0.27, 0.31$ ) than for the women ( $r = 0.52, 0.44$ ).

The age-related decrease of standing height was examined in 1088 Belgian men and 957 women initially aged 36-55 yr. Over a 30-yr follow-up, the decrease in stature was greater among inactive individuals (54.0 mm in men, 62.5 mm in women) than in those who reported remaining at least moderately active (28.5 mm in men, 34.5 mm in women) (Sagiv et al., 2000). In other words, regular physical activity apparently halved the age-related loss of standing height in both sexes.

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A case-control survey of 14,261 adults (aged 50-79 yr) from 19 European countries (Silman et al., 1997) noted that after adjusting data for age, cigarette smoking and body mass index, walking or cycling  $>30 \text{ min}\cdot\text{d}^{-1}$  was associated with a lower risk of vertebral deformity in women (but not in men). In men, vertebral deformity was adversely associated with a history of very heavy physical activity earlier in life (an odds ratio of 1.5-1.7).

Any effect of habitual physical activity in reducing the risk of fractures is small in middle-aged samples, but this benefit becomes more evident with aging. In a survey of 3910 male and 3291 female Norwegians aged 35-65 yr, the only association observed was a reduced risk of "low energy" fractures in active versus inactive men (a relative risk of 0.9 for those reporting moderate physical activity and a relative risk of 0.6 for those engaging in vigorous physical activity) (Joakimsen et al., 1998).

A 1-yr survey of 3110 elderly Florida residents (average age 73 yr) found a lower incidence of fractures in men (15.6/1000) than in women (44.2/1000) (Sorock et al., 1988). The men showed a significantly lower risk if they took any physical activity (an odds ratio of 0.41) or reported walking a distance of 1.6 km  $>3$  times/wk (an odds ratio of 0.26). In women, the effects of physical activity were smaller, and not statistically significant (respective odds ratios of 0.76 and 0.60), perhaps because there were very few women who were taking any significant amounts of moderate or vigorous physical activity.

However, in Southampton, UK, a sample of 473 elderly patients with fractures of the proximal femur were age and sex matched with 600 control

subjects (Cooper et al., 1988). After statistical adjustments for body mass index, cigarette smoking, alcohol consumption, stroke and steroid treatment, the risk of a fracture tended to be increased by a lack of physical activity, particularly in the women; respective risk ratios were for a slow walking speed 1.6 in men and 2.6 in women; for walking less than  $30 \text{ min}\cdot\text{d}^{-1}$  2.7 in men and 0.9 in women, for infrequent muscle-loading 2.5 in men and 1.7 in women, and for a poor grip strength 1.9 in men and 2.7 in women.

In summary, regular physical activity has a beneficial effect upon both laboratory measures of osteoporosis and clinical indices such as vertebral deformity, shortening and fractures. In general, benefits of physical activity are seen to a greater extent in elderly women, because they begin with much lower levels of bone density than the men, but in some cases women fail to take sufficient exercise to realize their potential for positive change in bone structure.

### *Peptic Ulcer*

An analysis of middle-aged individuals (a sample of 8529 men and 2884 women) who were attending the up-scale Cooper Clinic in Dallas, TX found that in men (but not in women) the risk of developing a self-reported duodenal ulcer was lower in those who were habitually active (walking or jogging  $>16 \text{ km}/\text{week}$ ) than in those who were more sedentary, and that the beneficial association persisted after statistical adjustment for smoking and alcohol consumption (Cheng et al., 2000). Possible mechanisms of protection include the relief of stress and exercise-induced changes in immune function and gastric acid secretion. The lack of response in the women may again reflect

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a lower overall average intensity of physical activity.

### *Adenomas*

A case/control study of 310 men and 185 women in their 60s who were undergoing colonoscopy found that relative to inactive individuals, there was a substantially lower incidence of incident and metachronous adenomas of the colon and rectum in physically active men (respective odds ratios of 0.7 and 0.6), but active women apparently gained no such advantage. The authors of this report suggested that the reason for this sex difference might be difficulty in accurate classification of physical activity levels in women (Neugut et al., 1996). A further factor working against demonstration of an effect in the women was that a large proportion of the females, both cases and controls, were taking little or no physical activity.

### *Cancer*

A cross-sectional analysis of U.S. adults aged 70-82 yr (129 men, 119 women) identified tertiles of active energy expenditure using the DLW technique (Manini et al., 2009). The risk of cancer was inversely associated with active energy expenditure, in women only, but cardiovascular disease, hypertension, diabetes depression, osteoarthritis, osteoporosis and chronic lung disease were unrelated to the activity level in either sex (Manini et al., 2009).

Over the following 3 yr, mobility limitations were more likely to develop in men (but not in women) with a low level of active energy expenditure (Manini et al., 2009).

### *Summary*

Regular physical activity is associated with a reduced risk of a wide variety of chronic conditions in the elderly, as in middle-aged subjects. For many of the conditions considered, the direction of the association remains to be established by longitudinal research, although studies using laboratory markers of disease in ostensibly healthy individuals argue for a causal relationship. For most conditions and diseases, benefit is relatively similar for men and women. For some issues, a poorer initial health status gives women the potential for a greater response to an increase in physical activity, but on the other hand if moderate or vigorous physical activity is required for benefit, many elderly women may be unwilling or unable to undertake this.

### **Implications for Policy**

Although the reported level of physical activity is commonly lower in elderly women than in their male peers, a large proportion of both men and women in most developed societies are taking far less than the minimum levels of physical activity recommended to maintain health (American College of Sports, 1998; Chodzko-Zajko et al., 2009; Paterson et al., 2007).

It is possible to obtain a relatively objective measure of an individual's physical activity using a pedometer/accelerometer. This provides a benchmark of current status, and it would be useful to include such an assessment in each senior's medical file (Coleman et al., 2012). The prolonged wearing of a personal monitor might also serve to stimulate an increase in the individual's habitual physical activity.

Both cross-sectional associations and longitudinal studies point to a myriad of health benefits for seniors who place

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themselves in the upper tertile or quartile of physical activity for their age group, and those who are currently relatively sedentary should be encouraged to strive to reach this goal. For many, this will be possible through a gradual progression in their deliberate daily physical activity.

Progress will be facilitated if physicians and clinical physiologists pay due attention to sex differences in the types of activity that are preferred. Many older men still enjoy the stimulus of competition, but for women the availability of group walking and swimming programmes is more enticing. Where possible, perceived barriers to an increase of physical activity should be reduced or eliminated. For women, in particular, this may involve increasing the perceived safety of the exercise, finding an exercise companion and providing easy transportation.

The dose/response relationship between physical activity and health benefit requires further clarification in many conditions. But it appears that even if poor motivation, practical barriers or chronic disease prevent attainment of current public health goals, some health benefit will be obtained from less dramatic increases in the habitual activity of those who are currently sedentary, and such a progression should be encouraged.

### **Suggestions for further research**

Appropriate population sampling is critical to research. There is thus a need for further examination of the causes and extent of sex biases in recruitment to physical activity studies, and investigators must explore how such biases can be minimized. Absolute errors in most questionnaire assessments of physical activity are currently so large as to allow only the broadest of policy

recommendations. There remains scope to determine why such large errors are occurring, whether they are exacerbated in the elderly, whether they differ between men and women, and how they can be reduced. Although personal monitors such as pedometer/accelerometers are assumed to give much more accurate information than questionnaires, there remains scope for a further validation of personal monitoring devices against DLW estimates of energy expenditures when performing a wide range of physical activities under free-living conditions. Epidemiological studies provide some evidence of regional differences in patterns of physical activity, particularly between northern and southern Europe. This points to the need for a further examination of socio-cultural factors that influence the habitual activity patterns of elderly men and women, and a study of how cultural influences may be changing as women in various parts of the world become "liberated" from their traditional constraints. Information on secular trends has to-date been compromised by frequent changes in measuring instruments. There thus remains scope to establish long-term trends in active behaviour, and to assess how far these trends can be influenced by various types of health promotional campaign. Finally, there is need for a more precise definition of dose/response relationships between habitual activity and health. It will then become clearer which aspects of current patterns of physical activity it is advantageous to enhance.

### **Conclusions**

Many elderly men and women show undesirably low levels of habitual physical activity, and in general women

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engage in about 10% less active leisure than their male peers. In particular, women report less involvement in sport and moderate to vigorous activity than the men. Nevertheless, better health is associated with higher levels of physical activity in both sexes. Although the best health outcomes are likely with moderate to vigorous physical exercise, if women are unwilling or unable to engage in such activity, there may be merit in encouraging them to make a progressive increase in the lighter activities in which they are currently engaged. When promoting greater weekly physical activity, due account must be taken of the differing values that elderly men and women place upon physical activity (competition in the men, physical appearance, health and social contacts in the women). Sex differences in perceived barriers also need to be addressed, particularly cost, safety and lack of transport and a partner in women. Much research remains to be undertaken before most of the senior population attains that minimum level of regular physical activity that will ensure good health and freedom from physical disability. However, the social costs of ignoring this requirement are high, and those engaged in health research should focus greater attention upon the needs of the geriatric population.

### Authors' Qualifications

The authors' qualifications are: Roy J. Shephard M.B.B.S, M.D.[Lond.], Ph.D., LL.D., D.P.E., F.A.C.S.M. and Yukitoshi Aoyagi Ph.D.

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