Sedentary Behaviors and Health Outcomes Among Adults

A Systematic Review of Prospective Studies

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Context: Nowadays, people spend a substantial amount of time per day on sedentary behaviors and it is likely that the time spent sedentary will continue to rise. To date, there is no review of prospective studies that systematically examined the relationship between diverse sedentary behaviors and various health outcomes among adults.

Purpose: This review aimed to systematically review the literature as to the relationship between sedentary behaviors and health outcomes considering the methodologic quality of the studies.

Evidence acquisition: In February 2010, a search for prospective studies was performed in diverse electronic databases. After inclusion, in 2010, the methodologic quality of each study was assessed. A best-evidence synthesis was applied to draw conclusions.

Evidence synthesis: 19 studies were included, of which 14 were of high methodologic quality. Based on inconsistency in findings among the studies and lack of high-quality prospective studies, insufficient evidence was concluded for body weight–related measures, CVD risk, and endometrial cancer. Further, moderate evidence for a positive relationship between the time spent sitting and the risk for type 2 diabetes was concluded. Based on three high-quality studies, there was no evidence for a relationship between sedentary behavior and mortality from cancer, but strong evidence for all-cause and CVD mortality.

Conclusions: Given the trend toward increased time in sedentary behaviors, additional prospective studies of high methodologic quality are recommended to clarify the causal relationships between sedentary behavior and health outcomes. Meanwhile, evidence to date suggests that interventions aimed at reducing sedentary behavior are needed.

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Context

Sedentary behavior is a different construct than physical (in)activity, with both behaviors having different determinants.[1] In an editorial[2] of this journal, in 2007, Biddle made clear that the study of sedentary behavior was becoming popular and he encouraged to perform more research on sedentary behavior. In order to distinguish between light-intensity activities and sedentary behavior, in 2008, Pate and colleagues[3] provided a definition of sedentary behavior. Following that definition, sedentary behavior refers to activities that do not increase energy expenditure substantially above the resting level (1.0–1.5 METs) and it includes activities such as sleeping, sitting, lying down, watching TV, and other forms of screen-based entertainment.

Considering these examples of sedentary behaviors, it is clear that given the increasing availability of technology, people currently spend a lot of time on sedentary behaviors and it is likely that time spent sedentary will even continue to rise. To illustrate, based on results from the American Time Use Survey (ATUS), it appeared that watching TV accounted for about half of leisure time (www.bls.gov/news.release/pdf/atus.pdf). Also, many jobs nowadays involve much time spent sitting at work. Using data from a representative sample of Dutch households, Jans et al.[4] found that on average Dutch workers spent sitting about 7 hours per day, of which one third was at work. In addition, a study[5] among Chinese adults

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showed sedentary time, measured by accelerometer, to be made up most of the time, namely, 509 minutes per day.

Because most adults are working, and thus are more or less forced to sit continuously during a large part of the day, it is important to get insight into the potential adverse health effects of sedentary behaviors. In their systematic review, Van Uffelen and colleagues[6] examined the evidence on associations between occupational sitting and health risks and concluded that there currently is limited evidence for a positive relationship. Only in the last decade has the literature increased on the role of sedentary behavior in the development of adverse health outcomes, with studies[5,7,8] suggesting an independent adverse health effect of sedentary behavior. Very recently, Hamer et al.[9] found an independent association between sedentary behavior, indexed by TV- and screen-based time, and poorer health scores among adults.

Few reviews[10–12] have summarized the literature with respect to the health implications of sedentary behavior. However, those reviews focused on one type of sedentary behavior or one health outcome, with overweight and obesity being most frequently examined. Except for the review by Marshall and colleagues,[11] which performed a meta-analysis regarding the relationship between media use and body fatness among children and youth, the previous reviews did not perform a systematic approach in that they assessed the methodologic quality of the studies or used a best-evidence synthesis or meta-analysis to draw conclusions. Finally, in a review of studies on the effect of sedentary behavior on health, Pate et al.[3] concluded that most of the identified studies did rather measure insufficient levels of physical activity instead of measuring sedentary behavior. Thus to date, the health effects of different sedentary behaviors are still unclear. The aim of the present study was to systematically review the literature with respect to the relationship between diverse sedentary behaviors and health outcomes among adults taking into account the methodologic quality of the studies.

Evidence Acquisition

Identification and Selection of the Literature

A literature search was conducted in several electronic bibliographic databases, namely, PubMed, Embase, PsycINFO, and the Cochrane Library. The keywords used referred to the exposure (sedentary behavior); outcome (health-related); and study design (longitudinal designs). English written publications published between 1989 and February 25, 2010, were applied as a limit. As a systematic review to the relationship between sedentary behaviors and health among children and adolescents was performed simultaneously, the search was not limited to the adult population. However, for the purpose of this specific review, only studies that involved the adult population were included. Next to the search in electronic databases, the authors' personal databases and previous reviews and references of key publications were checked. Studies that examined the relationship between sitting and (low) back pain were excluded for two reasons. First, the type of sedentary behavior was assumed to be specific, namely, sitting at work. Second, Chen and colleagues[13] recently performed a systematic review on this relationship.

The titles and abstracts of all citations derived from the search were screened independently by two of the current authors. In case of uncertainty to either include or exclude the study, the full paper was read. To be included in the review, the study had to meet the following criteria:

1. The study had to have a longitudinal design, either prospective or retrospective.
2. The study had to involve an adult, nonpatient population (i.e., average age >18 years).
3. The study had to measure sedentary behavior as defined by Pate et al.[3]

Data Extraction and Quality Assessment

Data were extracted from all studies selected with regard to the study population, follow-up duration, type and measurement of sedentary behavior, type and measurement of the health outcome, statistical analysis, and results. The selected studies were evaluated on their methodologic quality. In doing so, two of the authors independently scored the quality of each study according to a standardized set of predefined criteria (Table 1).[14–16] The list consists of 15 items, which distinguished between informativeness (I, $n=6$) and validity/precision (V/P, $n=9$). Each quality criterion was rated as *positive* (1), *negative* (0), or *unknown* (?). A positive score was given if the publication provided an informative description of the criterion at issue and met the quality criterion. A negative score was given in case of an informative description, but an inadequate execution or lack of description of the item concerned. In case of an unclear or incomplete description of the item, a question mark was given.

The results of the scorings were compared and differences were discussed during a consensus meeting. If, after discussion, agreement could not be reached, one of the other authors was consulted to achieve the final judgment. If necessary, the first author of the publication was contacted by e-mail to provide additional information as to the item that had a question mark in the scoring. They were given a time frame of 2 weeks, and received one reminder. For each study, a total quality score was assigned by counting the number of items scored positively

Table 1. Criteria list for assessment of the methodologic quality of prospective studies[14–16]

Criteria[a]	I, V/P	% studies meeting the item
Study population and participation (baseline)		
1. Adequate description of source population[b]	I	84
2. Adequate description of sampling frame, recruitment methods, period of recruitment, and place of recruitment (setting and geographic location)[b]	I	58
3. Participation rate at baseline at least 80%, or if the nonresponse was not selective (show that baseline study sample does not significantly differ from population of eligible subjects)	V/P	16
4. Adequate description of baseline study sample (i.e., individuals entering the study) for key characteristics (*n*, age, gender, SB, and health outcome)[c]	I	79
Study attrition		
5. Provision of the exact *n* at each follow-up measurement	I	42
6. Provision of exact information on follow-up duration	I	89
7. Response at short-term follow-up (up to 12 months) was at least 80% of the *n* at baseline and response at long-term follow-up was at least 70% of the *n* at baseline	V/P	58
8. Information on not selective nonresponse during follow-up measurement(s)[d]	V/P	26
Data collection		
9. Adequate measurement of SB: done by objective measures (i.e., accelerometry, heart rate monitoring, observation) and not by self-report (self-report = –; no/insufficient information = ?)	V/P	11
10. SB was assessed at a time prior to the measurement of the health outcome	V/P	95
11. Adequate measurement of the health outcome: objective measurement of the health outcome done by trained personnel by means of standardized protocol(s) of acceptable quality and not by self-report (self-report = –; no/insufficient information = ?)	V/P	53
Data analyses		
12. The statistical model used was appropriate[e]	V/P	100
13. The number of cases was at least 10 times the number of the independent variables	V/P	100
14. Presentation of point estimates and measures of variability (CI or SE)	I	95
15. No selective reporting of results	V/P	100

[a]Rating of criteria: + = yes; – = no; ? = unknown
[b]Adequate = sufficient information to be able to repeat the study
[c]+ is given only if adequate information is given on all items.
[d]+ is given only if nonselective dropout on key characteristics (age, gender, sedentary behavior, health outcomes) is reported in the text or tables.
[e]+ is given if a multivariate regression model was used.
I, criterion on informativeness; SB, sedentary behavior; V/P, criterion on validity/precision

on the validity/precision (V/P) criteria. A study was considered of high quality if the methodologic score was at least 5 of 9.

Levels of Scientific Evidence

After summarizing the included studies, it appeared that the studies were very heterogeneous, especially with regard to the type and measurement of sedentary behavior and the health outcome. Additionally, of those studies that examined the same health outcome, the statistical analysis varied among the studies, including the categorization of the independent variable (sedentary behavior) resulting in different types of effect sizes (e.g., hazard ratio [HR]; OR; risk ratio [RR]; or beta) making statistical pooling impossible. Therefore, to synthesize the methodologic quality of the studies and to be able to draw conclusions regarding the relationship between sedentary behavior and the health outcome, a

best-evidence synthesis was applied,[14,16] consisting of the following three levels:

1. Strong evidence: consistent findings in multiple (≥2) high-quality studies;
2. Moderate evidence: consistent findings in one high-quality study and at least one low-quality study, or consistent findings in multiple low-quality studies;
3. Insufficient evidence: only one study available or inconsistent findings in multiple (≥2) studies.

Similar to previous reviews that applied this best-evidence synthesis,[14,16–18] results were considered to be consistent when at least 75% of the studies showed results in the same direction, which was defined according to significance ($p<0.05$). If there were two or more high-quality studies, the studies of low methodologic quality were disregarded in the evidence synthesis.

Evidence Synthesis

Search and Selection

The search resulted in a total of 10,555 records (4994 from PubMed, 4564 from Embase, 457 from PsycINFO, and 540 from Cochrane Library). After removing the duplicate publications, a total of 8424 publications remained. After screening the titles and abstracts, 137 full papers were read. Of those, most were excluded because the study applied a cross-sectional design or the study applied a definition of sedentary behavior that did not meet the criterion. Finally, 19 prospective studies were included.[19–37] The characteristics of these studies are presented in Appendix A (available online at www.ajpm-online.net).

Methodologic Quality Assessment

The scoring of the 19 prospective studies led to a disagreement of 17%. The majority of the studies ($n=14$) was of high quality. The proportion of studies meeting the quality items varied considerably per item, with only 11% (2 of 19 studies) scoring positive on the objective measurement of sedentary behavior.

Sedentary Behavior—Health Outcomes

Sedentary behavior—body weight/BMI gain. There were three prospective studies,[20,21,37] of which two were of high quality, investigating the relationship between sedentary behavior and body weight gain. Further, two high-quality studies[22,31] investigated the relationship between sedentary behavior and BMI gain. Of these five studies, four[21,22,31,37] assessed the time spent on TV viewing, showing inconsistent results. For example, Coakley et al.[21] found a significant relationship between the time spent on TV/VCR and self-reported body weight gain among those aged 45–54 years, but no significant relationship was found among those aged >55 years. These findings were supported by the studies of Jeffery et al.[31] and Crawford et al.,[22] who found no significant relationship between the time spent TV viewing and objectively measured body weight/BMI gain among men and women, respectively. In contrast, the more recent study of Raynor et al.[37] found TV viewing time to be related to self-reported body weight gain over a 1-year period, beta(t)=0.12 (3.89), $p<0.001$. Based on the inconsistent findings among the prospective studies identified, there is *insufficient evidence* for a longitudinal relationship between sedentary behavior and body weight/BMI gain.

Sedentary behavior—overweight or obesity. Four prospective studies[26,30,34,35] were identified that examined the relationship between sedentary behavior and the risk for overweight or obesity. The study of Graff-Iversen et al.[26] found increased ORs for overweight (BMI≥27) among women performing light, moderate, or heavy work compared to those with sedentary work; ORs varied from 1.18 (95% CI=1.04, 1.34) to 1.67 (95% CI=1.38, 2.03). However, no significant relationships were found for men. Although a different cut-off point for overweight was used (BMI≥25), Meyer et al.[34] did not find a significant relationship between the time spent TV viewing and the risk for developing overweight over a period of 6 years. In contrast, Novak et al.[35] found for both men and women viewing more programs on TV per week to be at increased risk for developing overweight (OR=1.51, 95% CI=1.05, 2.18, and OR=1.73, 95% CI=1.09, 2.76, respectively) over 14 years. The study of Hu et al.[30] was the only study that investigated the relationship with self-reported obesity using a cut-off point of BMI≥30. They found different results for the different sedentary behavior measured used (Appendix A, available online at www.ajpm-online.net). Based on the inconsistent findings among the studies, there is *insufficient evidence* for the relationship between sedentary behavior and the risk for overweight or obesity.

Sedentary behavior—waist gain. Only one low-quality prospective study[33] examined the relationship between sedentary behavior and waist gain, both measured by self-report. Over a period of 6 years, they found a significant relationship with an increase of 20 hours per week of viewing TV to be related to 0.30 (0.12) cm waist gain ($p=0.02$). Based on this single study, there is *insufficient evidence* for the relationship between sedentary behavior and waist gain.

Sedentary behavior—type 2 diabetes. Two low-quality prospective studies[29,30] investigated the relationship between sedentary behavior and the incidence of type 2 diabetes in men and women, respectively. The study of Hu et al.[29] reported a significant relationship between the

time spent TV viewing and type 2 diabetes among 37,918 male health professionals (p-value for trend 0.02). In 2003, Hu et al.[30] reported the relationship over a 6-year period between various sedentary behaviors and incidence of diabetes type 2 in 68,497 women. They found significant positive relationships for TV viewing, sitting at work or away from home or driving, and other sitting at home with those viewing TV for at least 6 hours per week being at increased risk of developing diabetes type 2 compared to those viewing 0–1 hours per week. Based on the consistent findings of these two low-quality studies, there is *moderate evidence* for a significant positive relationship between the time spent sitting and the risk for type 2 diabetes.

Sedentary behavior—cardiovascular disease risk factors. Four high-quality prospective studies[19,24,25,28] examined the relationship between sedentary behavior and CVD risk factors. Beunza et al.[19] studied different sedentary behaviors, TV viewing, PC use, and driving, and found no significant relationship for any sedentary behavior and self-reported incidence of hypertension. The study of Fung et al.[25] investigated the relationship between the weekly time spent TV/VCR viewing and several biomarkers of CVD risk, namely, cholesterol measures (e.g., total, LDL, HDL, triglycerides); leptin; fibrinogen; insulin; C-peptide; and HbA1c among male health professionals. With the exception of leptin ($p<0.05$), no significant relationships were found for any of the CVD biomarkers. Finally, the remaining two studies[24,28] examined the relationship between objectively measured sedentary behavior and insulin resistance, with the study of Ekelund et al.[24] also investigating the relationship with self-reported TV/video viewing.

Although a trend was observed for the relationship between sedentary time and fasting insulin ($p=0.07$) over a 1-year follow-up period, no significant relationship was found with the homeostatis model assessment (HOMA-IR) score, nor for the time spent TV/video viewing and fasting insulin or HOMA-IR score.[24] Helmerhorst et al.[28] had a longer follow-up time, namely, 5.6 years, and found the objectively measured time spent sedentary significantly related to insulin resistance. Based on the findings of the studies identified, there is *insufficient evidence* for a significant relationship between sedentary behavior and various CVD risk factors.

Sedentary behavior—endometrial cancer. Two high-quality studies[27,36] investigated the relationship between sedentary behavior and a specific type of cancer, namely, endometrial cancer. Patel et al.[36] measured the time spent sitting outside work and found no significant relationship with endometrial cancer. This was in contrast to the study of Gierach et al.,[27] who found a significant trend for the time spent sitting and the incidence of endometrial cancer, with those sitting at least 5 hours per day being at increased risk. However, this significant relationship was not observed for the time spent viewing TV/videos ($p=0.26$). Based on the inconsistencies found between and within the two studies identified, there is *insufficient evidence* for the relationship between sedentary behavior and endometrial cancer.

Sedentary behavior—mortality. Three studies[23,26,32] investigated the relationship between sedentary behavior and mortality. All three studies applied a different sedentary behavior measure. The low-quality study of Graff-Iversen et al.[26] assessed the relationship between sedentary work and mortality and did not find a significant relationship with the exception of heavy occupational physical activity, which was related significantly to a lower risk of mortality. The second prospective study identified, which was of high methodologic quality,[32] investigated the relationship between sitting time and mortality among 17,013 Canadians aged 18–90 years. The outcomes included mortality from all causes, mortality from CVD, mortality from cancer, and mortality from other diseases based on the Canadian mortality registrations.

No significant relationship was found for mortality from cancer. However, for all-cause, CVD, and other mortality, there were significant relationships between the time spent sitting and mortality, with an increased risk of those who reported sitting for at least three quarters of their time compared to those sitting for none of the time.[32] These findings were confirmed by the most recent study,[23] which also was rated as of high quality. They found that each 1-hour increment in TV/videos viewing appeared to be significantly related with all-cause mortality and CVD mortality; no significant relationship was found for mortality from cancer.[23]

Based on the findings of the two high-quality studies, there is *strong evidence* for a relationship between sedentary behavior and mortality from all causes and from CVD, but *no evidence* for the relationship between sedentary behavior and mortality from cancer.

Discussion

The present review aimed to systematically summarize the literature with regard to the relationship between sedentary behavior and health outcomes, taking into account the methodologic quality of the studies. Despite the start date of the literature being 1989, the majority (12 of 19) of the studies included were published after 2005. This indicates that the topic of sedentary behavior as a probable independent predictor for certain health outcomes has recently gained increased attention in the lit-

erature. Based on the studies identified, moderate evidence for a significant positive relationship between the time spent sitting and incidence of type 2 diabetes was found. Further, strong evidence was found for a relationship between sedentary behavior and all-cause and CVD mortality, but not for mortality from cancer.

However, in contrast to some suggestions of previous literature,[10,38] the conclusion of strong evidence for a positive relationship between sedentary behavior and weight outcomes could not be confirmed. Despite a different sitting-time measure (i.e., occupational sitting), this review's conclusions were in line with those of Van Uffelen et al.[6] They also found mixed results among the cross-sectional studies, with the prospective studies not being able to confirm a positive relationship between occupational sitting and BMI. The conclusion of the present review of insufficient evidence was partly due to the lack of high-quality prospective studies. In particular, for waist gain, there was only one prospective study. For the other body weight outcomes, there were multiple studies, but findings from those studies were mixed.

These inconsistencies may be caused by differences in the methodology used in the studies. For example, it appeared that the two studies that objectively measured body weight (and height) did not detect a significant relationship between TV viewing and weight/BMI gain, whereas the remaining three studies that measured body weight by self-report did find a positive relationship with sedentary behavior. This pattern was also true for the studies that examined the risk for overweight and obesity: those measuring overweight or obesity by self-report found significant positive relationships. These results are remarkable and emphasize the importance of objectively measured body weight and height, as it is known that self-reported weight and height are less accurate and valid than objectively measured body weight and height, and therefore they may lead to misclassification of overweight or obesity.[39]

Comparison Findings with Previous Reviews

To the best of our knowledge, this review is the first one that attempted to summarize the literature regarding the longitudinal relationship between diverse sedentary behaviors, excluding occupational sitting, and diverse health outcomes. Despite differences in methodology between this review and previous ones, results can be compared. Based on the findings of the cross-sectional studies, the review of Williams et al.[38] concluded generally positive associations between TV viewing and indicators of overweight.

However, inconsistent results were found based on the longitudinal studies included, thereby supporting the present review's conclusion. With respect to other health outcomes, they also found similar results based on longitudinal studies. For example, the positive associations observed between TV viewing and lipoproteins or blood pressure/hypertension from cross-sectional studies were not confirmed by the few longitudinal studies in their and the present review. It thus seems that the evidence to date is insufficient to conclude that there is a longitudinal relationship between sedentary behavior and body weight and certain other health outcomes, such as CVD risk factors. In this context, it is worthwhile to emphasize that the insufficient evidence is partly due to lack of studies with a high level of methodologic quality.

Methodologic Issues

Although most studies were considered to be of high quality, there are a few methodologic issues that are worth mentioning.

First, the large majority of the studies (17 of 19) measured sedentary behavior by self-report, with different recall periods used (e.g., 12 months, a typical day, or 1 week). From a study[40] that tested the reliability and validity of the instruments measuring sedentary behavior, it appeared that the validity of self-report instruments for non-occupational sedentary behaviors varies considerably. The authors therefore recommended the development of a reliable and valid self-report instrument covering diverse sedentary behaviors. Because a substantial proportion of the adult population is working, and thus spends considerable (sitting) time at work, the development of a self-report instrument that measures the entire range of sedentary activities, including time spent sitting at work, seems necessary. In this context, it is worthwhile to consider the possible influence on this review's findings, which mainly reflect the relationship between self-reported sedentary behavior and health outcomes.

Another methodologic issue that needs to be addressed, concerns the follow-up period. The length of the follow-up measurement was not included in the methodologic quality criteria list, but may explain the inconsistencies in the results among studies. For example, two studies[24,28] investigated the relationship between objectively measured sedentary behavior and insulin resistance. The study of Ekelund et al.[24] did not find a significant relationship after 1 year, but with a median follow-up of 5.6 years, Helmerhorst et al.[28] found sedentary time to be significantly related to insulin resistance. Although this was not valid to all health outcomes, it is recommended for future studies to apply a follow-up duration of at least a few years, especially for those health outcomes for which it is plausible that effects will occur only after a longer period.

Mechanisms for the Observed Relationships

There are several theories explaining the relationship between sedentary behavior and health outcomes. In their publication, Williams et al.[38] provided a framework for the potential relationship between TV viewing and health outcomes. According to their framework, TV viewing is related indirectly to overweight and obesity through increased energy intake and decreased energy expenditure. Further, these two energy-balance–related behaviors can influence health outcomes either directly or indirectly, through overweight and obesity. Findings from this review showed various results for the independent relationship between sedentary behaviors and weight outcomes, including overweight and obesity, and moderate evidence for a relationship with type 2 diabetes.

These results suggest that there is a direct relationship between sedentary time and type 2 diabetes. It is therefore interesting to conduct a mediation analysis investigating the relationship between sedentary behavior and type 2 diabetes and to examine the contribution of energy-balance–related behaviors (diet and physical activity) and overweight and obesity in this relationship. Considering the role of body fatness on inflammatory factors,[41] it also is recommended to include body fatness as an outcome in studies regarding the relationship with sedentary behavior. Next to its possible independent effect on health outcomes, fatness may be an important mediator in the relationship between sedentary behavior and health. Based on studies of the role of fatness in the relationship between fitness and inflammatory pathways, it would also be interesting to examine eventual gender differences.

Further, a mediation analysis may be valuable to explain other relationships. For example, how can the lack of evidence for the relationship with some CVD risk factors be explained, in combination with the strong evidence for a relationship between sedentary behavior and mortality from CVD? Another mechanism that has been proposed to explain the relationship between sedentary behavior and health outcomes, include changes in cardiac stroke volume and output.[32,42] In addition, based on animal studies,[12,43] a physiologic link with sedentary time and lipoprotein lipase activity has been found. The present review's conclusion of strong evidence for CVD mortality supports those findings. However, there are still uncertainties in the underlying behaviors and (physiologic) mechanisms that likely explain the health effects of prolonged sedentary time. It is thus a topic that needs further research.

Strengths and Limitations

There are several strengths and weaknesses of this review. The strengths include the systematic approach in the literature search and in the assessment of the methodologic quality of each study, and the use of a best-evidence system based on which conclusions were drawn. Moreover, a search in diverse databases was performed and only prospective studies were included. Because the current review was limited to prospective studies, it is possible to report on longitudinal relationships and not on associations only. Although the studies applied different statistical models, they all analyzed the change in health outcome in particular. The studies either examined the change in health by the difference between baseline and follow-up values (delta scores) or by applying an ANCOVA in which the value at follow-up was the dependent value and adjusting for the baseline value.

A weakness of this review however is the subjectivity of the rating. Although the quality rating was done by two reviewers independently, the scoring may be subject to bias. To minimize this, the authors were contacted to provide information about the question marks of the quality criterion of concern. However, some authors did not reply, resulting in the study being scored as low-quality. To illustrate, if the author(s) had replied positively on one validity and precision item, the study quality would change from low to high and consequently lead to the conclusion of strong evidence for a relationship with type 2 diabetes (instead of moderate evidence).

This example thus highlights the sensitivity of the best-evidence system used. Thus, a meta-analysis would have been preferred. However, as described earlier, the studies identified were too heterogeneous for such a quantitative analysis. It is thus worthwhile to consider that the heterogeneity in methods among the studies, such as the use of different measurement instruments of sedentary behavior or health outcome and the variation in follow-up duration, may have led to the inconsistent findings among the studies. Nevertheless, we believe the studies can be compared in a best-evidence synthesis, especially as conclusions were drawn for each specific health outcome. Also, except for two studies, all measured sedentary behavior by self-reports and generally showed comparable findings. Finally, by presenting all characteristics of each study and its results (Appendix A, available online at www.ajpm-online.net), readers may interpret the results themselves.

Conclusion

This review of prospective studies showed moderate evidence for an independent relationship between sedentary time and type 2 diabetes. In addition, strong evidence was found for sedentary behavior to be related to all-cause and CVD mortality, but not for mortality from cancer. Because of mixed results and the lack of prospective studies, there was insufficient evidence for a relationship between sedentary time and weight outcomes and CVD risk

factors. Given the increasing modern technology with an increasing availability of computers, TV, DVD, and other automatic devices, the trend of spending time in sedentary behaviors involving prolonged sitting is likely to continue. Considering this trend, the increasing prevalence of obesity and type 2 diabetes, and the present results, interventions aimed at the reduction of the time spent on sedentary behavior together with the promotion of physical activity should be developed.

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Appendix

Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.amepre.2010.10.015.