Background: Television viewing time is associated with obesity risk independent of leisure-time physical activity (LTPA). However, it is unknown whether the relationship of TV viewing time with body mass index (BMI) is moderated by other domains of physical activity. Methods: A mail survey collected height; weight; TV viewing time; physical activity for transportation (habitual transport behavior; past week walking and bicycling), for recreation (LTPA), and in workplace; and sociodemographic variables in Adelaide, Australia. General linear models examined whether physical activity domains moderate the association between BMI and TV viewing time. Results: Analysis of the sample (N = 1408) found that TV time, habitual transport, and LTPA were independently associated with participant’s BMI. The interaction between TV time and habitual transport with BMI was significant, while that between TV time and LTPA was not. Subgroup analyses found that adjusted mean BMI was significantly higher for the high TV viewing category, compared with the low category, among participants who were inactive and occasionally active in transport, but not among those who were regularly active. Conclusions: Habitual active transport appeared to moderate the relationship between TV viewing time and BMI. Obesity risk associated with prolonged TV viewing may be mitigated by regular active transport.

Keywords: walking, bicycling, commuting, sedentary behavior, obesity

Obesity is a major threat to public health. In Australia, the prevalence of obesity has more than doubled in the last 2 decades. There is a strong case that the pattern of adults’ daily lives has become more sedentary due to an increase in screen-based passive recreation, labor-saving technology at work or at home, and a greater reliance on cars, and that such lifestyle attributes are contributing to a global obesity epidemic.

It has been suggested that sedentary behavior contributes to obesity through behavioral and physiological processes. Potential behavioral mechanisms linking sedentary behavior and metabolic risk include the displacement of light-intensity physical activity and increased energy intake while sitting (snacking). In addition, building on recent epidemiological and laboratory studies, Hamilton and colleagues have suggested that prolonged sitting leads to poor health outcomes through unique physiological mechanisms, which are distinct from those resulting from a lack of physical activity.

Among sedentary behaviors, television (TV) viewing time occupies the largest proportion of sedentary leisure time. Prolonged TV viewing time increases the risk of obesity, the metabolic syndrome, and type 2 diabetes. Thus, it is meaningful to explore behaviors that are amenable to change and may be protective against the health risks posed by prolonged TV viewing time. Studies are consistent in showing that high volumes of TV viewing time contribute to an increased odds of obesity, independent of participation in leisure-time physical activity (LTPA); higher volumes of TV viewing time increases the odds of having a higher body mass index (BMI) even for those who engage in a higher level of LTPA. However, little is known about whether physical activity in other domains moderate the association of TV viewing time with BMI.
Walking or bicycling to work and to other utilitarian destinations (active transport) could be a potentially effective means of combating obesity. A European study showed that middle-aged men who actively commuted to work had a reduced risk of subsequent weight gain, independent of participation in occupational and leisure-time physical activity. Studies have also shown that being overweight or obese is positively associated with greater use of automobiles for commuting and negatively associated with time spent walking or bicycling to work. However, it is not known whether prolonged TV viewing time contributes to the risk of higher BMI among those who are active in different domains of physical activity.

We examined whether active transport moderates the relationship between TV viewing time and BMI, in a sample of Australian adults. We also examined the potential moderation of the relationship by other domains of physical activity.

### Methods

#### Sample and Data Collection

This study was conducted during 2003 to 2004 in Adelaide, Australia. Detailed methods of data collection have been described elsewhere. Briefly, the study sample was drawn from residential addresses within 32 neighborhoods in urban and suburban areas of Adelaide. Residents of private dwellings aged between 20 and 65 were randomly chosen from the study areas and invited to participate. Those who were eligible and agreed to participate were sent a questionnaire. Due to the large amount of data requested from the participants, 2 different surveys were mailed, with a 6-month interval between the first (N = 2650) and the second (N = 2194). This study used data from the second survey. The final response rate, calculated as the proportion of households that completed the survey among the total 23128 eligible households in the sampled neighborhoods, was 11.5%. Of the total participants who answered the second survey (N = 2194), this study focused on those who had a job (or unpaid work) outside of their home (N = 1524). Completion and return of the survey form was taken as active consent to participate. The Behavioural and Social Sciences Ethics Committee of the University of Queensland approved the study.

#### Measures and Instruments

##### Outcome Variable

The outcome measure of the study was participant’s body mass index (BMI), calculated from self-reported height and weight.

**TV Viewing Time.** The independent variable, TV viewing time, was determined by asking participants to recall the number of days they watched TV or videos in the past 7 days and the average amount of TV time for those days. The item to measure TV viewing time has been found to have reasonable 1-week test-retest reliability (intraclass correlation coefficient: 0.82) and validity (Spearman’s rank-order correlations with a 3-day activity log: 0.3, P < .01). TV viewing time was dichotomized into low and high levels around the median (90 min/day).

**Habitual Transport Behavior.** An instrument developed by Miilunpalo et al., which asked how often participants commute on foot or by bicycle, was employed to identify the habitual transport behavior. Commuting was defined broadly in this instrument and included going to work, going shopping, taking a child to day care or to school, or running other errands that last at least 10 minutes each time. Participants were asked to choose from the following options: (1) never commute on foot or by bicycle and it would be out of the question in my case; (2) hardly ever commute on foot or by bicycle and have never really thought about doing it; (3) hardly ever commute on foot or by bicycle, but might start doing it within the next 6 months; (4) occasionally commute on foot or by bicycle and expect to continue like this; (5) occasionally commute on foot or by bicycle, but intend to start commuting more regularly within the next month; (6) have been commuting mainly on foot or by bicycle, but only in the last 6 months; (7) have been commuting mainly on foot or by bicycle for longer than 6 months, but less than 2 years; or (8) have been commuting mainly by foot or by bicycle for longer than 2 years. Those who chose response 1, 2, or 3 were categorized as “inactive,” 4 or 5 as “occasionally active,” and 6, 7, or 8 as “regularly active,” respectively.

**Walking and Bicycling for Transport in the Previous Week.** To examine whether long-term and short-term active transport behaviors play the same role in the relationship of TV viewing time with BMI, the amount of past week walking and bicycling for transport (WBT) was also determined using the long version of the International Physical Activity Questionnaire (IPAQ). Participants were asked to recall the frequency (days per week) and average duration of WBT in the last 7 days. The total amount of WBT was categorized into tertiles: low (0–5 min/day), medium (5–25 min/day), and high (> 25 min/day).

**Leisure-time Physical Activity in the Previous Week.** Time spent in leisure-time physical activity (LTPA) in the previous week was also measured using the IPAQ. Participants reported the frequency and daily duration of vigorous-intensity, moderate-intensity, and walking activities during leisure time in the last 7 days. The total amount of LTPA was categorized into tertiles: low (0–10 min/day), medium (10–40 min/day), and high (> 40 min/day).

**Occupational Physical Activity in the Previous Week.** Time spent in occupational physical activity (OPA)
was included because it may confound the relationship between BMI, active transport and LTPA. The IPAQ was used to determine the amount of OPA from the frequency and average duration of vigorous-intensity, moderate-intensity, and walking activities in workplace in the last 7 days.

**Sociodemographic Attributes.** Variables collected from respondents included age, gender, educational attainment, and annual household income.

**Data Analysis**

A series of analyses were conducted to examine in what way different physical activity domains (habitual transport, WBT, LTPA, OPA) are involved in the relationship between BMI and TV viewing time. First, we ran a general linear model to examine the independent associations of BMI with TV viewing time and the physical activity domains, adjusting for age, gender, education, and income. Then, general linear models were used to assess the interaction terms between TV viewing time and each of the physical activity domains with BMI. Where significant interaction was observed, the sample was stratified by activity category, and adjusted mean BMI for TV viewing time categories was calculated for each subgroup. Analyses were conducted using SPSS Version 15.0 and SAS Version 9.1. Statistical significance was accepted at the level of 0.05 (at the level of 0.10 for interaction terms).

**Results**

After excluding participants with extreme BMI values (less than 15 kg/m² and more than 50 kg/m², n = 11) and those with missing values (n = 105), data from 1408 participants were analyzed. Table 1 shows the characteristics of the study sample by the habitual transport behavior category. A greater percentage of participants who were regularly active in transport had higher educational attainment and lower income, compared with the other groups. Those in the regularly active transport category also had lower mean BMI, and spent longer time in WTB and LTPA in the previous week, compared with those who were inactive or occasionally active in transport. TV viewing time and OPA did not differ across the habitual transport behavior categories. Two measures of active transport (habitual transport category and WBT levels) had a significant, fair level of agreement ($\kappa = 0.26, P < .001$). TV viewing time was weakly correlated with WBT ($r = .05, P = .08$) and with LTPA ($r = -.06, P < .05$), but not with OPA ($r = .02, P = .40$).

Significant bivariate associations of BMI with TV viewing time ($P < .001$), the levels of WBT ($P < .05$), and LTPA ($P < .001$) were observed. OPA was not associated with BMI ($P = .17$), thus it was not included in further analyses. Table 2 shows the results of general linear model predicting BMI using TV viewing time, habitual transport, WBT, and LTPA, adjusting for sociodemographic variables. It was found that TV viewing time, habitual transport, and LTPA were independently associated with BMI.

The interaction terms with TV viewing time were examined for habitual transport and LTPA. (WBT was not examined as it was not independently associated with BMI.) The interaction between TV viewing time and habitual transport behavior, adjusting for LTPA and sociodemographic variables, approached significance ($P = .088$, between inactive and regularly active categories). On the other hand, the interaction of TV viewing time with LTPA, adjusting for habitual transport category and sociodemographic variables, was not significant even

### Table 1  Sample Characteristics by Habitual Transport Behavior Category

<table>
<thead>
<tr>
<th></th>
<th>Habitual transport behavior category</th>
<th>Total</th>
<th>Inactive</th>
<th>Occasionally active</th>
<th>Regularly active</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td></td>
<td>1408</td>
<td>484 (34%)</td>
<td>522 (37%)</td>
<td>402 (29%)</td>
<td>–</td>
</tr>
<tr>
<td>Gender, % men</td>
<td></td>
<td>38%</td>
<td>41%</td>
<td>35%</td>
<td>40%</td>
<td>ns</td>
</tr>
<tr>
<td>Mean age, year (SD)</td>
<td></td>
<td>44.0 (11.6)</td>
<td>44.3 (11.2)</td>
<td>43.5 (11.3)</td>
<td>44.1 (12.6)</td>
<td>ns</td>
</tr>
<tr>
<td>Education, % with university education</td>
<td></td>
<td>55%</td>
<td>48%</td>
<td>57%</td>
<td>60%</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Income, % $41600 per annum or more</td>
<td></td>
<td>61%</td>
<td>62%</td>
<td>65%</td>
<td>53%</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>% of high TV viewers (≥90 min/day)</td>
<td></td>
<td>49%</td>
<td>51%</td>
<td>49%</td>
<td>48%</td>
<td>ns</td>
</tr>
<tr>
<td>Mean TV viewing time, min/day (SD)</td>
<td></td>
<td>100.0 (81.9)</td>
<td>100.4 (82.0)</td>
<td>100.0 (77.7)</td>
<td>99.6 (86.9)</td>
<td>ns</td>
</tr>
<tr>
<td>Mean WBT, min/day (SD)</td>
<td></td>
<td>25.7 (37.7)</td>
<td>15.7 (30.3)</td>
<td>21.3 (32.6)</td>
<td>43.2 (45.3)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Mean LTPA, min/day (SD)</td>
<td></td>
<td>37.0 (52.1)</td>
<td>27.8 (44.6)</td>
<td>40.8 (56.1)</td>
<td>43.2 (53.8)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Mean OPA, min/day (SD)</td>
<td></td>
<td>102.4 (170.3)</td>
<td>103.5 (164.1)</td>
<td>97.9 (169.0)</td>
<td>106.9 (179.2)</td>
<td>ns</td>
</tr>
<tr>
<td>Mean BMI, kg/m² (SD)</td>
<td></td>
<td>25.8 (4.8)</td>
<td>26.6 (5.2)</td>
<td>25.7 (4.5)</td>
<td>24.9 (4.6)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*Abbreviations: WBT, walking and bicycling for transport in the previous week; LTPA, leisure-time physical activity in the previous week; OPA, occupational physical activity in the previous week.*
between 2 extreme categories (P = .17). This suggests that the relationship of TV time with BMI may be different between inactive and regularly active transport categories, but no such moderation is evident for different levels of LTPA. Table 3 shows adjusted mean BMI for each group of habitual transport behavior category. The analyses were adjusted for LTPA and sociodemographic variables. Among those who were inactive and occasionally active in transport, adjusted mean BMI was significantly higher for the high TV viewing category, relative to the low category. However, among those who were regularly active in transport, adjusted mean BMI did not differ significantly between the low and high TV viewing categories.

### Discussion

Consistent with previous studies, this study shows that prolonged TV viewing time is associated with higher BMI. However, habitual active transport was found to moderate the relationship between TV viewing time and BMI, after adjusting for LTPA in the previous week. For participants who were inactive and occasionally active in transport, higher TV time was associated with higher BMI, whereas BMI did not differ across TV time category for those who were regularly active in transport. In contrast, the significant association between longer TV viewing and higher BMI remains the same across levels of LTPA. No moderation of the BMI-TV time relationship was evident for our measures of short-term transport.
activity (WBT) and occupational activity (OPA). The finding for LTPA is consistent with those of previous studies showing associations of TV viewing with BMI independent of participation in recreational physical activity.\textsuperscript{10,11,15} It may be argued from our findings that long-term, regular physical activity for transportation may be more effective in reducing the deleterious effects of TV viewing on metabolic health than is physical activity for recreation.

A potential reason for the moderation of the BMI-TV time relationship observed only for habitual transport behavior may be that those who are active in transport are likely to spend less time sitting while commuting, in comparison with those who are inactive in transport, whereas LTPA is known to be mostly independent from sedentary behavior. Another possible reason may be the frequency of activity. Regularly active transport users are likely to be active on most weekdays, while LTPA may occur less frequently. Considering that prolonged TV viewing time was significantly associated with higher BMI for those who were occasionally active in transport, the frequency of physical activity may be a factor relevant to reducing obesity risk in the presence of prolonged TV viewing time.

It has to be noted that transport-related walking and bicycle use measured in the short term (WBT in the previous week) was not independently associated with BMI. Although the level of agreement between the habitual transport behavior category and the category created from WBT was fair, past week walking and bicycling for transport may be less stable and possibly incidental. Thus, it can be argued that long-term, active transport behavior on a regular basis may be needed to reduce the risk of obesity from prolonged TV viewing. This argument is partly supported by a study in which undertaking frequent and habitual walking were found to be effective in reducing the deleterious effects of TV viewing on metabolic health than is physical activity for recreation.

The findings also confirmed the role of TV viewing on weight status, which has been shown in past studies.\textsuperscript{10,11,15} The majority of our study participants (71%) did not engage in regular active transport. For them, prolonged TV viewing time was positively associated with higher BMI. Among those for whom an active mode of transport is not a feasible option, reducing TV viewing time may be a more realistic goal to help prevent weight gain.

**Strengths and Limitations**

Strengths of the study include the use of multiple domains of physical activity measured in a relatively large sample. Most of the previous research examining the relationship between weight status and physical activity focused on LTPA, with very few studies addressing other types of physical activities.\textsuperscript{25,26} Also, we used 2 measures of transport behavior; 1 aimed to capture a long-term habit (6 months), and the other measured a short-term duration (past week). Furthermore, we identified potential health benefits of active transport by comparing it with LTPA, which has been researched extensively and considered an important health-enhancing behavior.

A limitation of our study is that the questionnaire did not ask about the long-term recreational physical activity habits. Although LTPA and sedentary behavior are known to be largely independent from each other, it is of interest to examine whether habitual physical activity for recreation may be protective against obesity risk associated with prolonged sedentary behavior. The long-term measure of transport behavior was originally developed to classify participants into the stages of behavior change (ie, precontemplation, contemplation, action, and maintenance). We collapsed the response items into 3 categories to identify a long-term pattern of transport behavior. Although we found a fair agreement between the category of habitual transport behavior and WBT levels, which can be seen as some degree of concurrent validity, lack of reliability and validity of this measure and is a limitation of this study. In addition, potential overlap between the response categories of this instrument may have resulted in misclassification. The cross-sectional nature of the study, which precludes any causal inference about the observed relationships, and the reliance on self-report measures are further limitations of the study.

**Conclusions**

Our findings warrant further research on the role of active transport in obesity prevention. Promoting active transport appears to be a promising approach as it can increase physical activity as well as reduce sedentary behavior on a regular basis. However, longitudinal and intervention studies are needed to investigate to what extent active transport is effective in weight maintenance and reduction. Further, the synergy between different domains of activity, for example, between physical activity for transport and for recreation, and between sedentary and active behaviors, is not well understood and needs to be explored in future research. It is also worthwhile to examine environmental and policy factors conducive to active transport. Features of the built environment and access to public transport could be a structural determinant of the adoption and maintenance of active transport and have the potential to prevent weight gain.\textsuperscript{27,28} Increasing the understanding about modifiable environmental attributes that could promote active transport will be helpful to develop environmental policies for obesity prevention.

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References


