Medicine & Science in Sports & Exercise, Publish Ahead of Print
DOI: 10.1249/MSS.0000000000001243

12-year Television Viewing Time Trajectories and Physical Function in Older Adults

Natasha Reid[1], Genevieve N. Healy[1,2,3,4], Robin M. Daly[5], Peter Baker[1], Elizabeth G. Eakin[1], David W. Dunstan[1,3,6,7,8], Neville Owen[1,3,6,9,10], and Paul A. Gardiner[11,12]

[1]School of Public Health, The University of Queensland, Brisbane, Australia.

[2]School of Physiotherapy, Curtin University, Perth, Australia.

[3]Baker IDI Heart and Diabetes Institute, Melbourne, Australia.

[4]Mary MacKillop Institute of Health Research, Australian Catholic University, Melbourne, Australia.

[5]Institute for Physical Activity and Nutrition, Deakin University, Geelong, Australia.

[6]Department of Medicine, Alfred Hospital, Monash University, Melbourne, Australia.

[7]School of Public Health & Preventive Medicine, Monash University, Melbourne, Australia.

[8]School of Sport Science, Exercise and Health, The University of Western Australia, Perth Australia.

[9]Melbourne School of Population and Global Health, The University of Melbourne, Melbourne, Australia.

[10]Swinburne University of Technology, Melbourne, Australia.

[11]School of Medicine, The University of Queensland, Brisbane, Australia.

[12]Mater Research Institute, The University of Queensland, South Brisbane, Australia.

Corresponding Author

Dr Genevieve Healy, PhD

The University of Queensland, School of Public Health

Herston Rd, Herston

Brisbane, Queensland

Australia, 4006

Email: n.reid@uq.edu.au

Tel: +61 7 3365 5039

Fax: +61 (7) 3365 5540

This work was supported by National Health and Medical Research Council of Australia (Program Grant #566940 to N.O.; Centre of Research Excellence Grant #1057608 to G.N.H., E.G.E., N.O., and D.W.D., with a top-up scholarship provided to N.R.; Senior Principal Research Fellowship #1003960 to N.O.; Senior Research Fellowship #1078360 to D.W.D. and #511001 to E.G.E.; Career Development Fellowship #108029 to G.N.H); the National Health and Medical Research Council of Australia and Australian Research Council (Dementia Research Development Fellowship #110331 to P.A.G.); the Victorian Government's OIS Program (to N.O. and D.W.D.); and by the Australian Federal Government (Australian Postgraduate Award Scholarship to NR).

The AusDiab study co-coordinated by the Baker IDI Heart and Diabetes Institute, gratefully acknowledges the support and assistance given by: K. Anstey, B. Atkins, B. Balkau, E. Barr, A. Cameron, S. Chadban, M. de Courten, N. Htun, A. Kavanagh, D. Magliano, S. Murray, K.

Polkinghorne, J. Shaw, A. Tonkin, T. Welborn, P. Zimmet, and all the study participants. Also, for funding or logistical support, we are grateful to National Health and Medical Research Council (NHMRC grants 233200 and 1007544), Australian Government Department of Health and Ageing, Abbott Australasia Pty Ltd, Alphapharm Pty Ltd, Amgen Australia, AstraZeneca, Bristol-Myers Squibb, City Health Centre-Diabetes Service-Canberra, Department of Health and Community Services—Northern Territory, Department of Health and Human Services—Tasmania, Department of Health—New South Wales, Department of Health—Western Australia, Department of Health—South Australia, Department of Human Services—Victoria, Diabetes Australia, Diabetes Australia Northern Territory, Eli Lilly Australia, Estate of the Late Edward Wilson, GlaxoSmithKline, Jack Brockhoff Foundation, Janssen-Cilag, Kidney Health Australia, Marian & FH Flack Trust, Menzies Research Institute, Merck Sharp & Dohme, Novartis Pharmaceuticals, Novo Nordisk Pharmaceuticals, Pfizer Pty Ltd, Pratt Foundation, Queensland Health, Roche Diagnostics Australia, Royal Prince Alfred Hospital, Sydney, Sanofi Aventis, sanofi-synthelabo, and the Victorian Government's OIS Program. The funders of this study had no role in the data analysis or interpretation of the results. The authors declare no conflict of interest. The results of the present study do not constitute endorsement by ACSM and the results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

Abstract

Introduction: The purpose of this study was to identify trajectories of older adults' television viewing (TV) time over 12 years; and, to examine their associations with performance-based measures of physical function. *Methods*: Data on TV time (hours/week) and socio-demographic factors were collected at each assessment of the Australian Diabetes, Obesity and Lifestyle (AusDiab) Study (1999/2000; 2004/2005; 2011/2012), with objective measures of physical function (2.44m timed-up-and-go [TUG, seconds] and knee extensor test [KES, kg]) collected at the final (2011/2012) assessment. Regression analyses examined predictors of trajectory membership and associations with TUG and KES in those aged 60+ years in 2011/2012. *Results*: Six TV time trajectories were identified among the 1938 participants (aged 60-97, 54% female): consistently-low (9.7%); low-increasing (22.3%); moderate-decreasing (13.5%); moderate-increasing (30.3%); consistently-high (18.9%); and, high-increasing (5.2%). There were no statistically significant relationships with TUG ($p>0.05$). In the fully adjusted model, KES performance was significantly better in the consistently-low, low-increasing and consistently-high trajectories, compared to the moderate-increasing trajectory ($P < 0.001$, $R^2 = 0.33$). *Conclusion*: 12-year trajectories of TV time were associated with muscle strength in older adults. These findings suggest that patterns of sedentary behavior can be a determinant of muscle strength in later life.

Key Words: group-based trajectory modeling; muscle strength; performance; sedentary time.

INTRODUCTION

Addressing time spent in sedentary behaviors (waking activities with low energy expenditure and a sitting or reclining posture (34)), is now a preventive health target. Television viewing time (TV time) is not only the largest contributor to adults' leisure sedentary time(1, 38) but may also be more detrimental to older adults than other sedentary behaviors, such as reading, playing board games, writing, and socializing (16). Adverse associations of excess TV time with several health outcomes, such as overweight/obesity (41), increased blood pressure (40), type 2 diabetes (36) and metabolic syndrome (14) have been documented. Evidence for the detrimental association of excessive TV time with poor physical function, which is one of the highest sources of burden and poor quality of life for older adults (42), is also accumulating. However, studies examining this association have predominantly been cross-sectional (10, 15), with a notable lack of longitudinal studies.

Further, the few available longitudinal studies (2, 26, 35) have been limited by the statistical methods employed. Limitations include: using predefined cut-offs to determine patterns (e.g., <4 hours vs >8 hours of TV time) (26); investigating the average pattern of behavior change (e.g., remaining in the same category or changing categories over time); or, considering only baseline values of an exposure (2, 35). In contrast, data driven approaches, such as group-based trajectory modelling (GBTM) (25), may be more useful in identifying behavioral patterns. GBTM is a form of latent class growth modelling, identifying clusters of individuals following the same or similar trajectories (25). Unlike more traditional methods that rely on researcher determined groups, GBTM uses a data driven method to identify unobserved heterogeneity in the population and summarizes this into distinct trajectories with homogenous groups (25). This approach has three unique assumptions. Firstly, it does not presuppose the presence or absence of particular trajectories but rather relies on the observed data to dictate the best trajectory models. Secondly, it considers that change in behavior is important, rather than just the initial data point. Finally, it has the potential to distinguish possible heterogeneity of change in behavior, rather than describing an average pattern of change (23, 25). This is important because true behavioral trajectories may not be linear over time.

The aim of this study was to identify GBTM-derived trajectories of TV time and examine the associations of these trajectories with subsequent performance on tests of physical function in community-dwelling older adults. A secondary aim was to describe the characteristics of older adults within the TV time trajectories.

METHODS

Participants and procedures

The Australian Diabetes, Obesity and Lifestyle Study (AusDiab) is a longitudinal study examining the history of diabetes, pre-diabetes, heart disease and kidney disease in community dwelling Australian adults. Recruitment and measurement procedures have been described in detail previously (3, 12, 39). Briefly, baseline data was collected in 1999-2000 (T1) from those aged at least 25 years using a probabilistic sampling frame (12). Since then, two additional waves of data collection have occurred (2004/05 [T2] and 2011/12 [T3]). Of those initially eligible in 1999/00 (n=20,347), 55.3% (n = 11,247) agreed to participate and attended an on-site testing center where assessments of lifestyle behaviors (including TV time) were undertaken. Approximately 60% of eligible baseline participants returned to a testing center at T2 (n= 6,400), with 72% (n= 4,614) of those returning at T3. Performance-based physical function tests, including the 2.44m Timed Up-and-Go Test (TUG) and Knee Extensor Strength (KES) test were conducted within the testing center at T3. The population of interest was limited to participants who had data for at least surveys T1 and T3 and were aged ≥60 years at T3 (n = 2345). Analyses were then limited to participants who had complete data on all relevant outcome, exposure and risk factor measures (n = 1938; 83% of possible sample). Ethics approval was obtained by the International Diabetes Institute and Alfred Hospital Ethics committee. All participants provided written informed consent.

Television time

As reported previously (12), total television viewing time (hours/week) was ascertained by the same interviewer-administered questionnaire at each wave. Participants reported the total time spent watching television or videos, where this was the main activity, in the previous week on weekdays and weekend days (separately). Television viewing time was operationalized as TV time weekdays plus TV time weekend days in hours per week. This measure is sensitive to change (13), reliable (intra-class correlation from 1-week test-retest [95%CI] = 0.82 [0.75, 0.87]) and valid (criterion validity: comparison with a 3-day sedentary time log; $\rho = 0.30$, $p < 0.01$) (32).

Timed-up-and-go test

Instructions to complete the 8ft (2.44m) TUG test have been reported previously (27). Briefly, participants begin seated and are instructed to walk 2.44m, turn, walk back and return to a seated position. A shorter time to complete the TUG test (in seconds; measured by stopwatch), indicates better dynamic gait speed and mobility across a combination of three commonly performed functional activities of daily living (sitting, standing, walking and turning). This test has shown good reliability (ICC= 0.95), and relative validity against gait speed as a criterion (r = 0.61) (29).

Knee extensor strength test

Full instructions to complete the KES test have also been previously reported (27). Participants begin seated with their hip and knee at 90 degree angles and are asked to extend their leg as forcefully as possible for 2-3 seconds against a strap placed 5-10cm above their ankle joint. The KES is a measure of lower-limb isometric muscle strength (4), with greater force (in kilograms (kg)) indicating better knee extensor strength. This test has been shown to have good test-retest reliability (ICC > 0.9) (37) and good construct validity with other measures of muscle strength (r = 0.768) (4). The KES test is reported in total kg, adjusted for thigh length (in cm).

Sociodemographic variables

Several sociodemographic variables measured at T1 were evaluated as predictors of trajectory group membership and included as covariates in the association of TV time trajectory with TUG and KES. Demographic (age, sex, marital status, educational attainment, living arrangement, and employment status), behavioral (smoking status and leisure time physical activity), and health (self-rated health, previous angina, stroke or heart attack, and BMI) variables were evaluated as predictors of trajectory group membership. These were all also used as covariates in the association of trajectories with TUG and KES. Response categories can be found in Table 1.

Statistical analyses

Data processing and analyses were performed in STATA (version 13, College Station, TX, Stata Corporation). Statistical significance was set as two-sided $P < 0.05$. Descriptive statistics are presented as means and standard deviations (SD) for normally distributed data, median (25^{th}, 75^{th} percentile) for non-normal continuous data, or percentages for categories. Baseline characteristics (at T1) of included participants overall are described in Table 1, with characteristics within each trajectory group provided in supplemental content (see Table, Supplemental Digital Content 1, Baseline Characteristics of all Included Participants, Overall as Well as by Television Viewing Trajectory Pattern, From the AusDiab Dataset, http://links.lww.com/MSS/A873).

Identifying TV time trajectories. Group-based trajectory modelling (GBTM) was used to identify trajectories of TV time over 12 years using a user-contributed program for STATA (version 13, College Station, TX, Stata Corporation; downloaded from http://www.andrew.cmu.edu/user/bjones/traj and adapted from SAS procedure) (19). A poisson zero inflated model was used due to the large number of zero counts and non-normal distribution for the TV time variable. The magnitude and direction of each trajectory was estimated via separate intercepts and slopes. Six criteria were used to assess model fit: 1) the Bayesian Information Criterion (BIC) and the log Bayes Factor (2*ΔBIC)(18); 2) close correspondence between the estimated probability of group membership and the proportion actually assigned to that group; 3) average posterior probability of >0.70; 4) reasonably tight confidence intervals around the trajectory groups; 5) no less than 5% within each group; and 6) distinguishable groups in terms of their characteristics and outcomes (25). Model selection occurred in three stages. Firstly, a two-group model saturated with quadratic parameters was tested. One additional group was included in successive models and model fit was evaluated based on the Log Bayes Factor scale (*k* versus *k-1* model) (20). Secondly, the model with the best Log Bayes Factor was assessed on the other five model selection criteria described above. If it did not meet these criteria, the process was repeated with the *k-1* model. Lastly, once the optimal number of groups was determined, the level of polynomial function (i.e., quadratic, linear, and constant) for each group was reduced until each parameter reached statistical significance ($P < 0.05$; see Table, Supplemental Digital Content 2, Group based trajectory model of TV viewing time selection in a sample of community-dwelling older adults, http://links.lww.com/MSS/A874).

Regression analyses. The results of the GBTM led to our selecting two models to examine the data. First, a cumulative odds model was used to determine the factors that influence baseline clusters of TV time (i.e., clusters of individuals with the same or similar baseline scores; Table 2). The proportional odds assumption required for this model was tested and met for all variables. Secondly, a linear regression analysis was used to determine the association of each TV time trajectory with performance on the TUG and KES at T3. The trajectory with the most participants was chosen as the referent (21). TUG and KES were log-transformed to maintain normality and associations were examined unadjusted, age-adjusted only (see Table, Supplemental Digital Content 3, unadjusted and age-adjusted associations with TUG and KES, http://links.lww.com/MSS/A875) and fully adjusted for all covariates (age, sex, BMI, tertiary education, marital status, urban vs rural living, employment status, smoking status, leisure time physical activity, previous angina, stroke or heart attack, and known hypertension). Traditional regression analyses investigating the association of quartiles of baseline TV time with performance on TUG and KES were also undertaken (see Table, Supplemental Digital Content 4, association of quartiles of baseline TV viewing time with TUG and KES, http://links.lww.com/MSS/A876) to explore the extent to which GBTM provides further insights into the associations.

RESULTS

Analyses were conducted with 1938 participants with full data. At T1 participants were aged from 47 to 85 years (mean [SD] = 57.6 [7.3] years). At T3, participants were aged from 60-97 years (69.5 [7.3] years); 54% were female, the majority had attained tertiary level education (63%), were partnered (82%), lived in an urban city (65%), and identified as employed (full-time or part-time; 61%) with an average BMI of 27 $kg.m^{-2}$ (Table 1).

Television time trajectories

A stepwise model comparison approach was conducted to compare *k* class to the *k-1* class model using the model fit criteria described above, with results provided in supplemental table 2 (see Table, Supplemental Digital Content 2, Group based trajectory model of TV viewing time selection in a sample of community-dwelling older adults, http://links.lww.com/MSS/A874). Based on the data, six trajectory patterns of TV time were identified (Figure 1): consistently-low (9.7%); low-increasing (22.3%); moderate-decreasing (13.5%); moderate-increasing (30.3%); consistently-high (18.9%); and, high-increasing (5.2%). Baseline weekly TV times are reported in Table 1.

Predictors of trajectory group membership

Table 2 displays the results of the cumulative odds model for factors that influence baseline clusters of TV time. Participants in the consistently-low and low-increasing trajectories (32%; n = 629) were grouped into Cluster A (low baseline TV time). Participants in the moderate-increasing and moderate-decreasing trajectories (44%; n = 852) were grouped into Cluster B (moderate baseline TV time), and participants in the consistently-high and high-increasing trajectories (24%; n = 457) were grouped into Cluster C (high baseline TV time; reference group). The cumulative odds model was then applied to estimate the odds ratios (ORs) for the study predictors simultaneously across the clusters of TV time. This model compares the reference group against all others (i.e., Cluster C vs Cluster A and B simultaneously).

The results of the model revealed that older age, higher BMI and being a smoker were associated with increased odds of having high TV time compared to low and moderate TV time. Female gender, being tertiary educated and employed, and previous cardiovascular disease (angina, stroke or heart-attack) were associated with decreased odds of having high TV time compared to low or moderate TV time. When we compared each of the clusters separately to the reference category separately, similar patterns of significant associations emerged (data not shown).

Television time trajectory associations with TUG and KES performance

No statistically significant associations of trajectory group with TUG performance were observed ($P > 0.05$), with the number of seconds taken to complete the TUG similar across the six trajectory groups (maximum difference 0.6 seconds). For KES, the overall model was statistically significant ($P > 0.001$; $R^2 = 0.33$). Participants in the consistently-low ($\beta = 1.16$ kg

95% CI: 1.00, 1.35**,** *P* = 0.05), low-increasing (β = 1.18 kg 95% CI: 1.05, 1.35**,** *P* = 0.01), and consistently-high (β = 1.19 kg 95% CI: 1.00, 1.41**,** *P* = 0.04) trajectories performed significantly better on the KES test, compared with the moderate-increasing trajectory. No statistically significant differences were observed with the moderate-decreasing or high-increasing trajectories. Results are displayed in Table 3. In contrast, when we examined the association of quartiles of baseline TV time (Q1 = 0-5.75 h; Q2 = 6-11.6 h; Q3 = 12-17.5 h; Q4 = 18-115 h; Q4=ref) with TUG and KES, no statistically significant associations were observed with either measure in the fully adjusted models (*P* > 0.05; see Table, Supplemental Digital Content 4, Regression Coefficients (β) for Association of Quartiles of Baseline TV Viewing Time With Performance on the TUG and KES Tests in the Fully-Adjusted Model, http://links.lww.com/MSS/A876).

DISCUSSION

This was the first prospective study to identify and examine associations of TV time trajectories with physical function in older adults. A six-trajectory model was found to best fit the data, with participants in the consistently-low, low-increasing and consistently-high trajectories observed to have greater lower-extremity muscle strength (KES performance) compared to those in the moderate-increasing trajectory. No statistically significant association between TV time trajectories and gait speed/mobility (TUG performance) was seen. Differences in trajectory group characteristics were observed between baseline clusters of TV time, with older age, higher BMI and smoking associated with higher TV time.

Previous studies have observed that sedentary time (e.g., TV time, self-reported and objectively measured sitting time) is associated with performance-based physical function (9, 17, 30, 33). The current study adds to this evidence base and extends it by using GBTM. Here, significant associations were observed with lower extremity strength, but not gait speed. The lack of observed association with TUG is consistent with a previous study on the same population (27) and the observation that modalities such as strength, balance, and gait speed begin to deteriorate at different times over the life course (8). Strength typically begins to deteriorate from age 50, whereas a reduction in gait speed (a large component of the TUG) typically accelerates after the age of 70. Therefore, the lack of any association with TUG in our study may relate to the fact that the mean age of our participants at baseline and follow-up was around 57 and 69 years, respectively.

It was also observed that participants in the consistently-high trajectory performed significantly better on the KES test compared to those in the moderate-increasing trajectory. Moderating factors such as illness may contribute to increasing TV time and poorer physical function (31) for participants in the moderate-increasing trajectory. Alternatively, high TV time has been correlated with increased adiposity (41), which may provide a training stimulus (by carrying more weight during incidental and planned activity) and thereby maintain muscle strength (6). Given that both low and high TV time appear to be associated with higher muscular strength, potential public health messages need careful consideration. However, the negative health effects of excessive TV time, and too much sitting more broadly, on cardiovascular health (14), mental health (7), and physical function (15) indicate that public health messages should remain focused on reducing and interrupting long bouts of sitting, consistent with current guidelines (11).

Of the six trajectories identified, three clusters of baseline TV time were present: low, moderate and high baseline TV time. As supported in previous literature, being older, having a higher BMI and being a current smoker were associated with higher TV time (5, 28). Conversely, female gender, education, employment status and previous health issues were associated with decreased TV time (5, 28). These correlates provide important, and consistent, sociodemographic characteristics by which intervention participants may be targeted in the future.

This study is one of the first to use GBTM to examine trajectories of TV time (or any type of sedentary behavior), particularly in older adults, and their association with functional outcomes. The use of this method extends the literature as it derives homogenous groups with potentially heterogeneous trajectories (25), with this technique allowing us to model change in TV time rather than relying on a single baseline measure or subjective cut-offs of high and low TV time. Indeed, using a more traditional approach of examining quartiles of baseline TV time in this study yielded different conclusions to those of the GBTM, with no significant associations observed. Further, the findings from the current study, as well as those that have explored TV time trajectories over 15 years in children and young adults (22, 24), suggest that TV is not stable over time: a concept that is poorly captured through traditional statistical approaches. This indicates that opportunities for intervention at critical life stages may be present and further research is needed to determine if such turning points exist (e.g., retirement). Findings from this study also suggest that historic TV time may be more predictive of physical performance than current TV time, evidenced by participants in the moderate-increasing and moderate-decreasing TV time trajectories performing similarly on both tests of physical function. Collectively, these results suggest that excessive TV time should be addressed earlier rather than later in the life course. With newer studies collecting longitudinal data on sedentary behavior, GBTM is potentially a powerful tool to examine those data and the extent to which changes in exposure impact health.

The longitudinal design and the recruitment of a geographically diverse sample were strengths of this study; however, there was notable attrition in the sample size from survey one to three and limited variation in TUG scores. The findings of this study are thus not generalizable beyond the characteristics of our participants. Only self-reported TV time was used, which does not strongly reflect objectively-assessed sedentary time. Objectively-measured sedentary behavior exposure across the whole day, including patterns of exposure, should also be examined. Further, the AusDiab study was not necessarily powered to address the research questions in this study, particularly with a sample limited only to older adults. However, the effect size obtained in the multiple regression are considered large. Lastly, although we adjusted our models for several confounding variables, we were not able to adjust for environmental or cognitive factors (due to missing values), which may be related to sedentary time and can impact on functional performance. The lack of data on these variables is a noted limitation within the literature (5, 28).

In summary, this is the first study to examine trajectories of TV time in older adults using GBTM. While this study did not observe a statistically significant association of TV time trajectories with gait speed/mobility (TUG performance), an association was observed for lower limb muscle strength (KES performance). With the majority of adults in the moderate-increasing trajectory of TV time, action is needed to counteract this negative trend. More longitudinal studies are needed to determine the causal relationship of sedentary time with other measures of physical function including muscle power, static and dynamic balance, coordination, flexibility, and body composition, as well as clinically relevant endpoints such as incident falls and fragility fractures. Future research would benefit from using a method such as GBTM to generate trajectories of sedentary time and to examine their correlates, including cognitive and environmental factors.

ACKNOWLEDGEMENTS

This work was supported by National Health and Medical Research Council of Australia (Program Grant #566940 to N.O.; Centre of Research Excellence Grant #1057608 to G.N.H., E.G.E., N.O., and D.W.D., with a top-up scholarship provided to N.R.; Senior Principal Research Fellowship #1003960 to N.O.; Senior Research Fellowship #1078360 to D.W.D. and #511001 to E.G.E.; Career Development Fellowship #108029 to G.N.H); the National Health and Medical Research Council of Australia and Australian Research Council (Dementia Research Development Fellowship #110331 to P.A.G.); the Victorian Government's OIS Program (to N.O. and D.W.D.); and by the Australian Federal Government (Australian Postgraduate Award Scholarship to NR).

The AusDiab study co-coordinated by the Baker IDI Heart and Diabetes Institute, gratefully acknowledges the support and assistance given by: K. Anstey, B. Atkins, B. Balkau, E. Barr, A. Cameron, S. Chadban, M. de Courten, N. Htun, A. Kavanagh, D. Magliano, S. Murray, K. Polkinghorne, J. Shaw, A. Tonkin, T. Welborn, P. Zimmet, and all the study participants. Also, for funding or logistical support, we are grateful to National Health and Medical Research Council (NHMRC grants 233200 and 1007544), Australian Government Department of Health and Ageing, Abbott Australasia Pty Ltd, Alphapharm Pty Ltd, Amgen Australia, AstraZeneca, Bristol-Myers Squibb, City Health Centre-Diabetes Service-Canberra, Department of Health and Community Services—Northern Territory, Department of Health and Human Services—Tasmania, Department of Health—New South Wales, Department of Health—Western Australia, Department of Health—South Australia, Department of Human Services—Victoria, Diabetes Australia, Diabetes Australia Northern Territory, Eli Lilly Australia, Estate of the Late

Edward Wilson, GlaxoSmithKline, Jack Brockhoff Foundation, Janssen-Cilag, Kidney Health Australia, Marian & FH Flack Trust, Menzies Research Institute, Merck Sharp & Dohme, Novartis Pharmaceuticals, Novo Nordisk Pharmaceuticals, Pfizer Pty Ltd, Pratt Foundation, Queensland Health, Roche Diagnostics Australia, Royal Prince Alfred Hospital, Sydney, Sanofi Aventis, sanofi-synthelabo, and the Victorian Government's OIS Program. The funders of this study had no role in the data analysis or interpretation of the results.

Author contributions: All authors contributed to this manuscript. The study was conceived and designed by NR, PAG and GNH. Data were provided through a larger study from NO, DWD, and RMD. Data were analysed by NR, PAG, PB and GNH; all authors were involved in the writing of the manuscript.

Conflict of Interest

The authors declare no conflict of interest. The results of the present study do not constitute endorsement by ACSM and the results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

REFERENCES

1. Australian Bureau of Statistics Web site [Internet]. *Australian Social Trends: Special Feature: Leisure at Home*. Canberra, Australia: ABS. 1995; [cited 2017 Jan 17]. Available from: http://www.abs.gov.au.
2. Balboa-Castillo T, Leon-Munoz LM, Graciani A, Rodriguez-Artalejo F, Guallar-Castillon P. Longitudinal association of physical activity and sedentary behavior during leisure time with health-related quality of life in community-dwelling older adults. *Health Qual Life Outcomes*. 2011;9:47.
3. Barr ELM, Magliano DJ, Zimmet PZ et al. *AusDiab 2005: The Australian Diabetes, Obesity and Lifestyle Study*. Melbourne, Australia: Baker IDI. 2005; [cited 2017 Jan 10]. Available from: https://www.baker.edu.au.
4. Bohannon RW. Measuring Knee Extensor Muscle Strength. *Am. J. Phys. Med. Rehabil.* 2001;80:13-8.
5. Chastin SF, Buck C, Freiberger E et al. Systematic literature review of determinants of sedentary behaviour in older adults: a DEDIPAC study. *Int J Behav Nutr Phys Act*. 2015;12:127.
6. Chastin SF, Ferriolli E, Stephens NA, Fearon K, Greig C. Relationship between sedentary behaviour, physical activity, muscle quality and body composition in healthy older adults. *Age Ageing*. 2012;41(1):111-4.
7. Da Ronch C, Canuto A, Volkert J et al. Association of television viewing with mental health and mild cognitive impairment in the elderly in three European countries, data from the MentDis_ICF65+ project. *Mental Health and Physical Activity*. 2015;8:8-14.

8. Daly RM, Rosengren BE, Alwis G, Ahlborg HG, Sernbo I, Karlsson MK. Gender specific age-related changes in bone density, muscle strength and functional performance in the elderly: a-10 year prospective population-based study. *BMC Geriatr*. 2013;13:71.

9. Davis MG, Fox KR, Stathi A, Trayers T, Thompson JL, Cooper AR. Objectively measured sedentary time and its association with physical function in older adults. *J. Aging Phys. Act.* 2014;22(4):474-81.

10. Dempsey PC, Howard BJ, Lynch BM, Owen N, Dunstan DW. Associations of television viewing time with adults' well-being and vitality. *Prev. Med.* 2014;69:69-74.

11. Department of Health Web site. [Internet]. Canberra, Australia: Australian Government; [cited 2017 Jan 17]. Available from: http://www.health.gov.au/.

12. Dunstan DW, Zimmet PZ, Welborn TA et al. The Australian Diabetes, Obesity and Lifestyle Study (AusDiab)—methods and response rates. *Diabetes Res. Clin. Pract.* 2002;57:119-29.

13. Gardiner PA, Clark BK, Healy GN, Eakin EG, Winkler EA, Owen N. Measuring older adults' sedentary time: reliability, validity, and responsiveness. *Med Sci Sports Exerc*. 2011;43(11):2127-33.

14. Gardiner PA, Healy GN, Eakin EG et al. Associations between television viewing time and overall sitting time with the metabolic syndrome in older men and women: the Australian Diabetes, Obesity and Lifestyle study. *J. Am. Geriatr. Soc.* 2011;59(5):788-96.

15. Hamer M, Stamatakis E. Screen-based sedentary behavior, physical activity, and muscle strength in the English longitudinal study of ageing. *PLoS One*. 2013;8(6):e66222.

16. Hu FB, Li TY, Colditz GA, Willet WC, Manson JE. Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women. *JAMA*. 2003;289(14):1785-91.

17. Ikezoe T, Asakawa Y, Shima H, Kishibuchi K, Ichihashi N. Daytime physical activity patterns and physical fitness in institutionalized elderly women: an exploratory study. *Arch. Gerontol. Geriatr*. 2013;57(2):221-5.

18. Jones BL, Nagin DS. A SAS procedure based on mixture models for estimating developmental trajectories. *Sociological Methods & Research*. 2001;29(3):374-93.

19. Jones BL, Nagin DS. Advances in Group-Based Trajectory Modeling and an SAS Procedure for Estimating Them. *Sociological Methods & Research*. 2007;35(4):542-71.

20. Kass RE, Raftery AE. Bayes Factors. *Journal of the American Statistical Association*. 1995;90(4):773-95.

21. Katz MH. *Multivariable Analysis: A Practical Guide for Clinicians and Public Health*. 3rd ed. Cambridge: Cambridge University Press; 2011.

22. Kwon S, Janz KF, Letuchy EM, Burns TL, Levy SM. Developmental Trajectories of Physical Activity, Sports, and Television Viewing During Childhood to Young Adulthood: Iowa Bone Development Study. *JAMA pediatrics*. 2015;169(7):666-72.

23. Louvet B. Latent Class Growth Modelling: A Tutorial. *Tutorials in Quantitative Methods for Psychology*. 2009;5(1):11-24.

24. McVeigh J, Smith A, Howie E, Straker L. Trajectories of Television Watching from Childhood to Early Adulthood and Their Association with Body Composition and Mental Health Outcomes in Young Adults. *PLoS One*. 2016;11(4):e0152879.

25. Nagin DS, Odgers CL. Group-based trajectory modeling in clinical research. *Annu. Rev. Clin. Psychol.* 2010;6:109-38.

26. Peeters GM, Lips P, Brown WJ. Changes in physical functioning over 6 years in older women: effects of sitting time and physical activity. *European Journal of Ageing*. 2014;11:205-12.

27. Reid N, Daly RM, Winkler EA et al. Associations of Monitor-Assessed Activity with Performance-Based Physical Function. *PLoS One*. 2016;11(4):e0153398.

28. Rhodes RE, Mark RS, Temmel CP. Adult sedentary behavior: a systematic review. *Am. J. Prev. Med.* 2012;42(3):e3-28.

29. Rikli RE, Jones JC. Development and validation of a functional fitness test for community-residing older adults. *Journal of Aging and Physical Activity*. 1999;7:129-61.

30. Rosenberg DE, Bellettiere J, Gardiner PA, Villarreal VN, Crist K, Kerr J. Independent Associations Between Sedentary Behaviors and Mental, Cognitive, Physical, and Functional Health Among Older Adults in Retirement Communities. *J Gerontol A Biol Sci Med Sci*. 2016;71(1):78-83.

31. Rozzini R, Frisoni GB, Ferrucci L, Barbisoni P, Bertozzi B, Trabucci M. The effect of chronic diseases on physical function. Comparison between activities of daily living scales and the Physical Performance Test. *Age Ageing*. 1997;26:281-7.

32. Salmon J, Owen N, Crawford D, Bauman A, Sallis JF. Physical activity and sedentary behavior: A population-based study of barriers, enjoyment, and preference. *Health Psychol.* 2003;22(2):178-88.

33. Santos DA, Silva AM, Baptista F et al. Sedentary behavior and physical activity are independently related to functional fitness in older adults. *Exp Gerontol*. 2012;47(12):908-12.

34. Sedentary Behaviour Research Network. Standardized use of the terms “sedentary” and “sedentary behaviours”. *Appl Physiol Nutr Metab*. 2012;37:540-2.

35. Seguin R, Lamonte M, Tinker L et al. Sedentary Behavior and Physical Function Decline in Older Women: Findings from the Women's Health Initiative. *J Aging Res*. 2012;2012:271589.

36. Smith L, Hamer M. Television viewing time and risk of incident diabetes mellitus: the English Longitudinal Study of Ageing. *Diabet. Med.* 2014;31(12):1572-6.

37. Sole G, Hamren J, Milosavljevic S, Nicholson H, Sullivan SJ. Test-retest reliability of isokinetic knee extension and flexion. *Arch. Phys. Med. Rehabil.* 2007;88(5):626-31.

38. Sugiyama T, Healy GN, Dunstan DW, Salmon J, Owen N. Is television viewing time a marker of a broader pattern of sedentary behavior? *Ann. Behav. Med.* 2008;35(2):245-50.

39. Tanamas SK, Magliano DJ, Lynch BM et al. *AusDiab 2012. The Australian Diabetes, Obesity and Lifestyle Study.* Melbourne, Vic, Australia: : Baker IDI Heart and Diabetes Institute. 2013; [cited 2016 Dec 20]. Available from: https://baker.edu.au.

40. Wijndaele K, Duvigneaud N, Matton L et al. Sedentary behaviour, physical activity and a continuous metabolic syndrome risk score in adults. *Eur J Clin Nutr*. 2009;63(3):421-9.

41. Williams DM, Raynor HA, Ciccolo JT. A Review of TV Viewing and Its Association With Health Outcomes in Adults. *American Journal of Lifestyle Medicine*. 2008;2(3):250-9.

42. World Health Organisation Web site [Internet}. *World report on ageing and health*. Geneva, Switzerland: WHO. 2015; [cited 2016 Dec 10]. Available from: http://www.who.int.

Figure Caption

Figure 1. Mean (95% Confidence Interval) trajectories of TV time over 12 years in Australian older adults based on six group-based trajectory modelling patterns (n = 1938).

Supplemental Digital Content

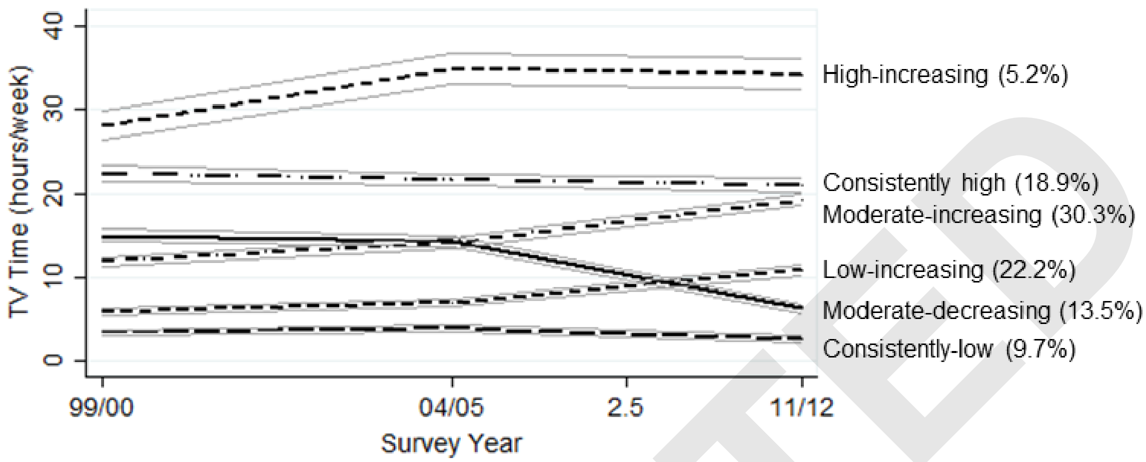
Supplementary Table S1. Baseline Characteristics of all Included Participants, Overall as Well as by Television Viewing Trajectory Pattern, From the AusDiab Dataset (n = 1938).

Supplementary Table S2: Group based trajectory model of TV viewing time selection in a sample of community-dwelling older adults (n=1938).

Supplementary Table S3. Regression Coefficients (β) of TV Viewing Time Trajectory Group With Performance on the TUG and KES Tests in the Unadjusted and age-Adjusted Models.

Supplementary Table S4. Regression Coefficients (β) for Association of Quartiles of Baseline TV Viewing Time With Performance on the TUG and KES Tests in the Fully-Adjusted Model.

Figure 1



40
30
20
10
0
TV Time (hours/week)
99/00
04/05
2.5
11/12
Survey Year
High-increasing (5.2%)
Consistently high (18.9%)
Moderate-increasing (30.3%)
Low-increasing (22.2%)
Moderate-decreasing (13.5%)
Consistently-low (9.7%)

Table 1. Baseline Characteristics of all Included Participants From the AusDiab Dataset (n = 1938).

Characteristics	
Age (years)	57.6 (7.3)
Female; n (%)	1037 (53.5)
BMI (kg/m^2)	27.1 (4.5)
Attained Tertiary Education; n (%)	1215 (62.7)
Married/DeFacto, n (%)	1585 (81.8)
Lives in Capital City; n (%)	1260 (65.0)
Currently Employed; n (%)	1174 (60.6)
Current smoker; n (%)	167 (8.6)
LTPA (hr/week)	4.8 (5.5)
TV time (hr/week)	12.9 (9.0)
Excellent/Very Good SRH; n (%)	966 (49.8)
Previous CVD; n (%)	140 (7.2)
Known Hypertension; n (%)	760 (39.2)
TUG, sec; median (25th, 75th)	6.4 (5.4, 7.6)
KES, kg.cm^2 [a]	0.6 (0.3)

Abbreviations: CVD, cardiovascular disease; KES, knee extensor strength; LTPA, leisure time physical activity; SRH, self-rated health; TUG, timed-up-and-go.

[a] KES is per centimeter of thigh length.

Values represent mean (SD) or number (percentage) unless indicated.

Table 2. The Cumulative Odds Model for the Factors That Influence Baseline TV Viewing Time Clusters (Comparing Cluster C [High TV Time] to Cluster A [Low TV Time] and B [Moderate TV Time]) (n=1938).

Characteristics	**OR**	**95% CI**	***P*-value**
Age (years)	1.02	1.00, 1.04	0.01
Female	0.79	0.67, 0.93	0.01
BMI	1.03	1.01, 1.05	0.01
Attained Tertiary Education	0.61	0.50, 0.76	<0.001
Married/DeFacto	1.00	0.82, 1.21	0.97
Lives in Capital City	0.88	0.73, 1.06	0.18
Currently Employed	0.64	0.51, 0.81	<0.001
Current Smoker	1.51	1.18, 1.94	0.01
LTPA (hr/week)	1.01	1.00, 1.02	0.11
Excellent/Very Good SRH	0.83	0.67, 1.02	0.07
Previous CVD	0.64	0.44, 0.94	0.02
Known Hypertension	1.09	0.87, 1.36	0.45

Abbreviations: CI, confidence interval; CVD, cardiovascular disease, defined as presence of previous stroke, angina or heart attack; LTPA, leisure time physical activity; SRH, self-rated health.

Table 3. Regression Coefficients (β) of TV Viewing Time Trajectory Group With Performance on the TUG and KES Tests in the Fully Adjusted Model (n=1938).

TV viewing Trajectory Group	Fully adjusted model		
	β	95%CI	*P*-value
Timed up-and-go test (sec)[a]			
Stable Low	0.98	0.91, 1.07	0.62
Low-Increasing	0.99	0.91, 1.07	0.75
Moderate-Decreasing	0.98	0.89, 1.07	0.66
Moderate-Increasing (ref)			
Stable High	0.98	0.91, 1.05	0.54
High-Increasing	0.93	0.81, 1.07	0.28
Knee extensor strength test (kg)[b]			
Stable Low	1.16	1.00, 1.35	0.05
Low-Increasing	1.18	1.05, 1.35	0.01
Moderate-Decreasing	1.15	0.98, 1.35	0.10
Moderate-Increasing (ref)			
Stable High	1.19	1.00, 1.41	0.04
High-Increasing	0.95	0.74, 1.23	0.71

Abbreviations: CI, confidence interval.

[a] back transformed from the log scale; adjusted for: age, sex, BMI, tertiary education, marital status, urban vs rural living, employment status, smoking status, leisure time physical activity, previous angina, stroke or heart attack, known hypertension; regression analysis is expressed as per second taken to complete TUG test.

[b] back transformed from the log scale; adjusted for: as TUG plus thigh length; regression analysis is expressed as per kg/thigh length.

Supplementary Table S1. Baseline Characteristics of all Included Participants, Overall as Well as by Television V

Pattern, From the AusDiab Dataset (n = 1938).

Characteristics		Trajectories of TV viewing Time				
	All (n=1938)	**Consist-Low Trajectory (n=188)**	**Low-Incr trajectory (n=441)**	**Mod-Decr trajectory (n=259)**	**Mod-Incr trajectory (n=593)**	**Consist Trajectory**
Age (years)	57.6 (7.3)	56.3 (7.6)	56.4 (7.0)	57.8 (7.8)	57.4 (6.9)	
Female; n (%)	1037 (53.5)	110 (58.5)	236 (53.5)	146 (56.4)	309 (52.1)	189 (51.9)
BMI (kg/m^2)	27.1 (4.5)	26.4 (4.6)	26.7 (4.4)	27.4 (4.3)	27.1 (4.6)	
Attained Tertiary Education; n (%)	1215 (62.7)	119 (63.3)	329 (74.6)	149 (57.5)	382 (64.4)	193 (53
Married/DeFacto, n (%)	1585 (81.8)	158 (84.0)	353 (80.0)	209 (80.7)	500 (84.3)	307 (84.3)
Lives in Capital City; n (%)	1260 (65.0)	134 (71.3)	308 (69.8)	141 (54.4)	393 (66.3)	229 (62.9)
Currently Employed; n (%)	1174 (60.6)	134 (71.3)	305 (69.2)	143 (55.2)	381 (64.2)	176 (48.4)
Current smoker; n (%)	167 (8.6)	14 (7.4)	24 (5.4)	28 (10.8)	53 (8.9)	
LTPA (hr/week)	4.8 (5.5)	4.0 (4.6)	4.8 (5.6)	4.9 (5.8)	4.8 (5.5)	
TV time (hr/week)	12.9 (9.0)	3.4 (2.9)	5.7 (3.2)	15.1 (6.8)	11.8 (4.1)	
Excellent/Very Good SRH; n (%)	966 (49.8)	98 (52.1)	247 (56.0)	127 (49.0)	392 (66.1)	161 (44.2)
Previous CVD; n (%)	140 (7.2)	16 (8.5)	31 (7.0)	15 (5.8)	44 (7.4)	
Known Hypertension; n (%)	760 (39.2)	66 (35.1)	147 (33.3)	114 (44)	220 (37.1)	168 (46.2)
TUG, sec; median (25th, 75th)	6.4 (5.4, 7.6)	6.4 (5.3, 7.4)	6.1 (5.3, 7.4)	6.4 (5.5, 7.7)	6.3 (5.4, 7.6)	6.5 (5.6, 7.9
KES, kg.cm^{2} [a]	0.6 (0.3)	0.6 (0.3)	0.6 (0.3)	0.6 (0.3)	0.6 (0.3)	

Abbreviations: CVD, cardiovascular disease; KES, knee extensor strength; LTPA, leisure time physical activity; SRH, self health; TUG, timed-up-and-go.

[a] KES is per centimeter of thigh length.

Values represent mean (SD) or number (percentage) unless indicated.

Supplementary Table S2: Group based trajectory model of TV viewing time selection in a sample of community-

(n=1938).

Model	**BIC**	**Log Bayes Factor (2*ΔBIC)**	**Estimated Group %**	**Actual Group %**	**Posterior probability**	**Significance of polynomial function**	
			49.59	49.65101	.9691478	0.48	
2 2	-23273.5		50.41	50.34899	.9683871	0.16	
			24.56	24.64807	.9506397	0.72	
			49.90	49.93115	.9448027	0.41	Improved Log Bayes Factor; all
2 2 2	-21853.1	2840.76	25.54	25.42078	.9382913	<0.05	other factors within limits
			24.36	24.32687	.949794	0.44	
			14.09	14.15631	.8770353	<0.001	
			39.89	39.57382	.9184056	<0.001	Improved Log Bayes Factor; all
2 2 2 2	-21265	1176.16	21.67	21.94301	.9386288	<0.05	other factors within limits
			12.33	12.33351	.9271311	<0.05	
			25.75	25.76513	.8875106	<0.001	
			35.24	34.99161	.9081002	<0.001	
			13.05	13.20523	.8919091	<0.001	Improved Log Bayes Factor; all
2 2 2 2 2	-20829.4	871.22	13.62	13.70451	.9225789	<0.001	other factors within limits
			9.70	9.74632	.9203123	<0.001	
			13.36	13.51657	.8891232	<0.001	
			22.76	22.29034	.8734098	<0.001	
			30.55	30.20790	.8734765	0.06	
			18.68	18.85660	.8692672	0.75	Improved Log Bayes Factor; all
2 2 2 2 2 2	-20610.8	437.2	4.95	5.38228	.9231775	<0.05	other factors within limits
			9.86	9.80311	.9182836	<0.001	
			11.66	11.85283	.8692195	<0.001	
			20.54	20.10133	.8668033	0.22	**Improved Log Bayes Factor but**
			29.41	28.67728	.8671529	0.25	**groups no longer**
			5.47	6.01184	.8415434	<0.001	**Additional group likely**
2 2 2 2 2 2 2	-20402	417.56	18.01	18.18667	.8663179	0.98	**reflecting missing values at T2**

			5.06	5.36695	.9118045	<0.05	
			9.70	9.74619	.9203228	<0.001	
			22.76	22.27786	.8733551	<0.001	
			13.36	13.52964	.8895644	<0.001	
			30.60	30.28302	.8742128	<0.001	
			18.78	18.92921	.8703545	0.05	
2 2 2 2 1 2	-20607	7.48	4.80	5.23407	.9265128	<0.001	Reducing polynomial order

Abbreviations: BIC, bayesian information criterion

Supplementary Table S3. Regression Coefficients (β) of TV Viewing Time Trajectory Group With Performance on the Tests in the Unadjusted and age-Adjusted Models.

TV viewing Trajectory Group	Unadjusted model			Age-adjusted model	
	β	95%CI	*P*-value	β	95%CI
Timed up-and-go test (sec)[a]					
Stable Low	0.93	0.85, 1.02	0.12	0.97	0.90, 1.06
Low-Increasing	0.92	0.84, 1.01	0.07	0.96	0.88, 1.04
Moderate-Decreasing	1.02	0.92, 1.13	0.73	1.00	0.91, 1.1
Moderate-Increasing (ref)					
Stable High	1.09	0.99, 1.20	0.08	1.00	0.92, 1.1
High-Increasing	1.13	0.97, 1.31	0.11	1.01	0.89, 1.15
Knee extensor strength test (kg)[b]					
Stable Low	1.11	0.94, 1.33	0.22	1.06	0.88, 1.27
Low-Increasing	1.21	1.03, 1.43	0.02	1.16	0.99, 1.36
Moderate-Decreasing	1.06	0.82, 1.36	0.67	1.08	0.85, 1.37
Moderate-Increasing (ref)					
Stable High	1.06	0.87, 1.28	0.57	1.16	0.95, 1.43
High-Increasing	0.85	0.65, 1.11	0.22	0.96	0.72, 1.28

Abbreviations: CI, confidence interval.
[a] back transformed from the log scale; regression analysis is expressed as per second taken to complete TUG test.
[b] back transformed from the log scale; always adjusted for thigh length; regression analysis is expressed as per kg/thigh length.

Supplementary Table S4. Regression Coefficients (β) for Association of Quartiles of Baseline TV Viewing Time With Performance on the TUG and KES Tests in the Fully-Adjusted Model.

	Fully adjusted model		
	β	**95%CI**	***P*-value**
Timed up-and-go test (sec)[a]			
Quartile 1	0.99	0.92, 1.07	0.79
Quartile 2	1.02	0.95, 1.09	0.58
Quartile 3	0.98	0.91, 1.06	0.67
Quartile 4 (ref)			
Knee extensor strength test (kg)[b]			
Quartile 1	1.13	0.98, 1.29	0.08
Quartile 2	0.97	0.83, 1.14	0.71
Quartile 3	1.07	0.94, 1.23	0.29
Quartile 4 (ref)			

Abbreviations: CI, confidence interval.

[a] back transformed from the log scale; regression analysis is expressed as per second taken to complete TUG test.

[b] back transformed from the log scale; always adjusted for thigh length; regression analysis is expressed as per kg/thigh length.