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**Associations Between Trajectories of Leisure-Time Physical Activity and Television Viewing Time
Across Adulthood: The Cardiovascular Risk in Young Finns Study**

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ABSTRACT

Background: The purpose of this study was to examine trajectories of leisure-time physical activity (LTPA) and television viewing (TV) time and their associations in adults over 10 years. **Methods:** The sample comprised 2934 participants (men, 46.0%) aged 24–39 years in 2001 and they were followed up for 10 years. LTPA and TV-time were assessed using self-report questionnaires in 2001, 2007 and 2011. Longitudinal LTPA and TV-time trajectories and their interactions were analyzed with mixture modeling. **Results:** Three LTPA (persistently highly active, 15.8%; persistently moderately active, 60.8%; and persistently low-active, 23.5%) and four TV-time (consistently low, 38.6%; consistently moderate, 48.2%; consistently high, 11.7%; and consistently very high, 1.5%) trajectory classes were identified. Persistently highly active women had a lower probability of consistently high TV-time than persistently low-active women ($P = .022$), while men who were persistently highly active had a higher probability of consistently moderate TV-time and a lower probability of consistently low TV-time than their persistently low-active counterparts ($P = .032$ and $P = .007$, respectively). **Conclusions:** Maintaining high LTPA levels were accompanied by less television viewing over time in women, but not in men. The associations were partially explained by education, body mass index and smoking.

Keywords: exercise, sedentary behavior, screen time, epidemiology

1 In recent decades, lifestyle has become more sedentary both during working hours and leisure time,
2 especially in high income countries.¹ Sedentary behavior is commonly defined as any waking behavior
3 characterized by an energy expenditure ≤ 1.5 metabolic equivalents while in a sitting, lying or reclining
4 posture,² and it should be distinguished from ‘physical inactivity’.³ Of various sedentary behaviors,
5 television viewing (TV) time still remains the most prevalent in Finland despite the proliferation of other
6 electronic devices.⁴ Increased TV-time has been found to be associated with more adverse health and
7 behavioral outcomes than other domains of sedentary behavior (e.g., using a computer, sitting during
8 transportation or sitting at work),^{5,6} and it may even lead to premature deaths during adulthood.⁷ On the
9 other hand, evidence shows that regular leisure-time physical activity (LTPA) has long-term health
10 benefits and contributes substantially to reduction of all-cause mortality.⁸

11
12 Although LTPA is one key intervention to reduce TV-time, the association between LTPA and TV-time
13 in adults remains to be clarified. According to a recent systematic review,⁹ only three observational
14 studies (two cross-sectional^{10,11}, one longitudinal study¹²) report a small or moderate inverse association
15 between the two variables. The review concluded that sedentary behavior does not displace moderate to
16 vigorous physical activity (MVPA) but more likely replaces light intensity physical activity when using
17 objective monitoring devices.⁹ Regarding associations between physical activity and TV-time trajectories,
18 only two longitudinal studies have explored such an association in youth.^{13,14} In both of these studies,
19 participants who maintained higher MVPA levels decreased their TV-time. Thus, the developmental
20 pathways of high MVPA and low TV-time could be related. However, there remains a lack of
21 longitudinal research exploring the linkages between LTPA and TV-time trajectories in adulthood. The
22 strength of the trajectory modeling is that rather than assuming the existence of distinct subgroups (i.e.
23 trajectories) in a population, it identifies them based on the population data.¹⁵

24
25 The aim of this study was threefold: 1) to describe developmental trajectory subgroups of both LTPA and
26 TV-time from young adulthood to early midlife over a 10-year follow-up period, 2) to identify the

linkages between LTPA and TV-time trajectory classes, and 3) to examine gender differences in such associations with taking into account age, education, body mass index (BMI), and smoking.

Methods

Participants

The Cardiovascular Risk in Young Finns Study (YFS) is an ongoing longitudinal population-based study consisting of six cohorts born in 1962, 1965, 1968, 1971, 1974 and 1977. The sample of healthy children and adolescents, aged 3, 6, 9, 12, 15, and 18 years, were randomly selected in 1980 from the five Finnish university cities with medical schools (Helsinki, Kuopio, Oulu, Tampere and Turku) and their surrounding communities ($N = 3596$, 83.0% of those who were first invited). The representativeness of study participants has been tested in 2001 by comparing their baseline (1980) characteristics to subjects lost to follow-up.¹⁶ The results showed participants to be older and more often women than subjects lost to follow-up. However, no significant differences were observed in LTPA or TV-time between participants and dropouts.^{17,18} The detailed description of the YFS, reasons for non-participation at follow-ups, and the characteristics of the participants have been reported elsewhere.¹⁶

For the present study, we chose 2001 as the baseline because that was the year when the self-reported TV-time was collected for the first time from all six cohorts. The participants were ages 24–39 years in 2001, and hence, 34–49 years in 2011. Those with missing information on both LTPA and TV-time variables were excluded. Complete data on all variables were available for 2934 healthy adults (men, 46.0%). The study protocol was reviewed and approved by the ethics committees of each of the five participating universities. The informed consent of all subjects was obtained in accordance with the Helsinki Declaration.¹⁶

Leisure-Time Physical Activity

52 LTPA in 2001, 2007 and 2011 was measured by a short self-report questionnaire. The questions consisted
53 of items on the intensity of LTPA, frequency of vigorous LTPA, hours spent on vigorous LTPA, average
54 duration of a LTPA session, and participation in organized LTPA. All items were first recoded
55 (1=inactivity or very low activity to 3=regular or vigorous activity) and then summed to create a physical
56 activity index ranging from 5 to 15,¹⁸ with high scores indicative of higher levels of LTPA. Test-retest
57 reliability coefficients of the LTPA values between 2001 and 2007 were $>.60$.¹⁸ The validity of the LTPA
58 values has been tested by showing a statistically significant correlation with the indicators of exercise
59 capacity (hypothetical maximal workload sustainable for 6 minutes) in a subsample for women ($r = .49$, P
60 $< .001$) and men ($r = .53$, $P < .001$)¹⁹ and with 7-day pedometer data obtained for total steps ($r = .24$, $P <$
61 $.001$) and aerobic steps ($r = .31$, $P < .001$).²⁰

62

63 **Television Viewing Time**

64 Self-reported TV-time in adulthood was measured with a question: “How many hours / minutes on average
65 per day do you spend watching television?”.^{17,21} Daily TV-time was recorded in minutes in 2001 and in
66 hours in 2007. In 2011, daily TV-time was measured in minutes separately for weekdays and weekend
67 days. A mean daily TV-time was calculated $[(5 \times \text{weekday}) + (2 \times \text{weekend})] / 7$. To have the same unit of
68 measurement for TV-time, all three measurements of daily TV-time were converted into one-hour
69 increments (hours of daily TV-time) prior to statistical analysis.

70

71 **Confounders**

72 In 2001, educational attainment was self-reported and measured as completed school years. Body weight
73 was measured with a Seca scale and body height with a Seca anthropometer (Vogel & Halke, Hamburg,
74 Germany). BMI was calculated as weight (kg)/height (m²). Smoking habits were obtained by a
75 questionnaire, those smoking on a daily basis were deemed as smokers.

76

77 **Statistical Analysis**

78 Descriptive statistics were calculated using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp.
79 Armonk, NY, USA) and further modeling was performed using Mplus, version 7.0.²² To identify LTPA
80 and TV-time trajectory subgroups in adulthood, latent profile analyses were conducted. Latent profile
81 analysis is a special case of a wider family of mixture models. The heterogeneous population is
82 considered to consist of subgroups of individuals, but the group membership is unknown. Mixture
83 modeling is a tool to statistically identify these homogeneous subgroups in a data driven way. First, the
84 latent profile analysis was carried out separately for both outcomes. The classification was based on the
85 means of the outcome measures in 2001, 2007 and 2011, and error variances were assumed to be equal
86 across classes. A model with two to six classes was fitted with gender and age covariates. Several fit-
87 indices were used to evaluate the goodness-of-fit of the latent profile analyses with different number of
88 classes: Akaike's information criterion (AIC), Bayesian information criterion (BIC), and sample-size
89 adjusted BIC (ABIC). The model with lower values of information criteria fitted the data better than an
90 alternative model with higher values. Furthermore, the following statistical tests were used to determine
91 the sufficient number of classes: Vuong-Lo-Mendell-Rubin likelihood ratio test (VLMR), Lo-Mendell-
92 Rubin (LMR) adjusted likelihood ratio test and parametric bootstrapped likelihood ratio test (BLRT). The
93 estimated model was compared to the model with one class less, and the low *p*-value of the test indicates
94 that the model with one class less was rejected in favor of the estimated model. The quality of the
95 classification was evaluated using entropy values and the average posterior probabilities for most likely
96 latent class membership (all ranging from 0 to 1 for both measures, value 1 indicating perfect
97 classification). The average posterior probabilities higher than 0.7 were considered acceptable.²²

98

99 Second, interrelationship between the longitudinal patterns of LTPA and TV-time was examined via
100 transition probabilities obtained from multinomial logistic regression analysis (i.e. dual trajectory model).

101 ²³ A multinomial logistic regression model was specified between the latent class variables: the latent
102 class variable of TV-time was regressed on the latent class variable of LTPA. Gender was allowed to be
103 associated with both the latent class variables and to moderate the association between LTPA and TV-

104 time.²⁰ The model was adjusted for potential confounding variables including age, education, BMI, and
105 smoking. The confounders were allowed to be associated with both the latent class variables. The
106 differences in the gender effect on latent class variable of TV-time across the LTPA classes (i.e.
107 interaction of gender and LTPA on TV-time) were tested. The adjusted transition probabilities (i.e.,
108 conditional probabilities for TV-time trajectory classes given to LTPA trajectory classes) were calculated
109 separately for men and women using the parameter estimates of the model and setting age, education and
110 BMI to their overall mean and smoker to non-smoker.

111
112 Missing data were assumed to be missing at random (MAR). Parameters of the models were estimated by
113 using the full information maximum likelihood (FIML) method with robust standard errors, which
114 enabled to use all the data available. The FIML method produced unbiased parameter estimates under
115 MAR assumption.

117 **Results**

118 Participants (1350 men and 1584 women) having at least one measure of LTPA or TV-time were
119 included in the study. For LTPA, 1431 participants (48.8%) completed all three measurements, 775
120 (26.4%) completed two, 675 (23.0%) completed one, and 53 (1.8%) did not have any information on
121 LTPA. For TV-time, the corresponding figures were 1566 (53.4%), 727 (24.8%), 636 (21.7%), and 5
122 (0.2%) participants, respectively. Descriptive characteristics of the study sample are presented in Table 1.

123
124 Adjusted models (adjusted for gender and age) with four classes provided the best fit for the LTPA data
125 (Table 2). VLMR and LMR were significant ($P < .001$ for both) for the models with less than five classes.
126 Model-fit of the models for LTPA improved with each step. However, after a four-class solution, some of
127 the average posterior probabilities dropped under acceptable level and, therefore, a four-class solution
128 was considered optimal. Longitudinal LTPA trajectory classes were identified: persistently very highly
129 active (3.8%), persistently highly active (17.5%), persistently moderately active (51.1%) and persistently

130 low-active (27.6%). To avoid small cell frequencies, the three-class solution for LTPA (persistently
131 highly active, 15.8%; persistently moderately active, 60.8%; and persistently low-active, 23.5%) was
132 considered more appropriate than a four-class solution for further analyses.

133
134 Model-fit of the adjusted models (adjusted for gender and age) for TV-time improved with each step
135 (Table 2). Because only small additional classes were extracted from the five-class solution forward (class
136 sizes <5%), the four-class solution was considered optimal. Longitudinal TV-time trajectory classes were
137 identified: consistently low TV-time (≤ 1 h/d, 38.6%), consistently moderate TV-time (2 h/d, 48.2%),
138 consistently high TV-time (≥ 3 h/d, 11.7%), and consistently very high TV-time (≥ 5 h/d, 1.5%). The last
139 two categories were combined to form “high” in order to further analyze an interpretable model. Quality
140 of the classification for both LTPA and TV-time was acceptable.

141
142 The estimation results of the multinomial logistic regression between latent classes of LTPA and TV-time
143 and moderating effect of gender are shown in Table 3. Participants in both persistently moderately active
144 and highly active classes had a lower probability of consistently high TV-time than those in the
145 persistently low-active class (unstandardized regression coefficient $b = -1.14$, standard error (*s.e.*) = 0.35,
146 $P = .001$ and $b = -2.35$, *s.e.* = 0.84, $P = .005$, respectively). These associations disappeared between the
147 persistently moderately active and low-active classes ($b = -0.60$, *s.e.* = 0.37, $P = .107$), and attenuated
148 between the persistently highly active and low active classes ($b = -1.44$, *s.e.* = 0.70, $P = .040$) after
149 additional adjustment for education, BMI and smoking. Gender effects on latent class variable of TV-time
150 differed across the LTPA classes. The gender (male) effect on the consistently high TV-time class was
151 positive within the persistently highly active ($b = 1.98$, *s.e.* = 0.90, $P = .027$) and moderately active ($b =$
152 0.83 , *s.e.* = 0.26, $P = .001$) classes. The male gender effect on the consistently moderate TV-time was also
153 positive within the persistently highly active class ($b = 0.96$, *s.e.* = 0.38, $P = .012$). All associations
154 concerning gender effects disappeared after adjustment for the confounding variables.

156 The age-adjusted latent transition probabilities between LTPA and TV-time trajectory classes for men and
157 women are illustrated in Figure 1 (A and B). The probability of the consistently high TV-time was lower
158 in persistently high active women than in persistently low-active women (3.9% vs. 22.9%, $P < .001$)
159 (Figure 1B). Among men, a similar tendency was observed but the difference between the classes was
160 only marginally significant (13.0% vs. 21.8%, $P = .055$) (Figure 1A). In addition, the probability of the
161 consistently low TV-time was higher in persistently high active women than in persistently low-active
162 ones (54.4% vs. 32.3%; $P = .006$), while no such difference was observed in men (28.9% vs. 38.8%, $P =$
163 .132).

164
165 After additional adjustment for BMI, education and smoking, the associations between the persistently
166 highly active and low-active classes on the consistently high TV-time attenuated in women (9.2% vs.
167 26.2%, $P = .022$) and disappeared in men (17.0% vs. 19.8%, $P = .571$). Men who were persistently highly
168 active had a higher level of consistently moderate TV-time than those who were persistently low-active
169 (68.4% vs. 51.1%; $P = .032$), while persistently high active men had a lower level of consistently low
170 TV-time than their persistently low-active counterparts (14.2% vs. 29.3%; $P = .007$). No group
171 differences were observed in either consistently moderate TV-time class or consistently low TV-time
172 class in women after additional adjustment for the covariates.

174 Discussion

175 The purpose of this study was to identify distinctive, potentially previously unobserved, stable and
176 changing LTPA and TV-time trajectories among Finnish men and women over a period of 10 years, and
177 to investigate how the identified LTPA trajectory classes were related to the TV-time trajectory classes.
178 Three LTPA (persistently highly active, persistently moderately active and persistently low-active) and
179 four TV-time (consistently low, consistently moderate, consistently high, and consistently very high)
180 trajectory classes were identified. We found an inverse association between persistently high LTPA and

181 excessive TV-time in women, but not in men. The differences were partially explained by education, BMI
182 and smoking.

183
184 The largest proportion of participants was identified in the persistently moderately active class. Even
185 though, worldwide, physical inactivity is usually more prevalent among women than among men, it is not
186 the case in Finland.²⁴ The present study supports this observation with the proportion of physically low-
187 active women being lower than physically low-active men. This study did not identify LTPA trajectory
188 classes describing change in the LTPA behavior in adulthood, while previous studies have either found
189 stable LTPA trajectory classes alone²⁵ or both increasing and decreasing classes in addition to stable
190 classes.²⁶ The inconsistent findings may be due to a wide range of ages or differences in methodology or
191 measurements.²⁷

192
193 The consistently moderate TV-time (2 h/d) class was found to be the most prevalent (48.3%), which
194 slightly differs with the previous result showing that the mean daily TV-time in 2015 was 2 hours and 54
195 minutes per day for Finnish adults aged 25–44 years.²⁸ Our study found a smaller proportion of adults in
196 the consistently high TV-time class and a larger proportion of adults in the consistently low TV-time class
197 as compared to the previous trajectory studies examining youth only.^{13,14,29} One explanation might be that
198 adolescents have more leisure time and fewer responsibilities when compared to adults and therefore they
199 simply spend more time watching television. Previous trajectory studies have identified TV-time change,
200 indicating that the TV behavior has not yet become stable in youth,^{13,29} whereas our results suggest that
201 the TV behavior stabilizes to a certain level during adulthood.

202
203 Few previous studies have examined the relationship between physical activity and TV-time or sedentary
204 behavior in either men or women. A significant negative association has been found between watching
205 television on a week day and high activity but only in men.³⁰ In contrast, a few previous studies have
206 reported TV-time to be inversely associated with physical activity among women.^{29,31} We found that

207 persistently active women spent less time watching television than persistently active men when
208 compared to their low active counterparts, suggesting that the amount of time women spend watching
209 television competes with time spend on LTPA. Meanwhile, excessive TV-time can coexist for men at
210 low, moderate or high LTPA level. This supports previous findings that sedentary behavior may be
211 independent of MVPA levels,⁹ and sedentary behavior and physical activity cannot be seen only as
212 functional opposites.^{1,30} In fact, it has been argued that less TV-time can potentially be an important target
213 to promote more active lifestyle for women but not for men due to these different TV-time and LTPA
214 patterns between genders.³¹

215
216 One possible explanation for gender differences in the association between LTPA and TV-time may be
217 that women experience clusters of multiple health behaviors more often than men.³² additionally, men and
218 women have different motivations for participation in LTPA: women have more extrinsic orientation
219 (appearance and physical condition) while men have more intrinsic orientation (mastery and
220 competition).³³ Thus, women's health-consciousness may have an additive effect on their decision-
221 making process in TV-time. Another possible explanation for these differences may be related to the use
222 of leisure time in Finland. Finnish women spend almost an hour more on household work than men on an
223 average day which may lead to those devoting more time to LTPA having less time for watching
224 television. Future research may investigate the motives for TV-time by gender to verify whether health-
225 related reasons or the use of leisure time affect the decision-making.

226
227 According to the crude analysis, the findings were as expected: participants who were persistently low-
228 active were more likely to watch more television than those who were persistently moderately active or
229 highly active. However, it is noteworthy that these significant associations mainly disappeared after
230 adjustment for education, BMI and smoking. Findings also indicated that the relationship between LTPA
231 and TV-time for both genders was affected by the confounding variables. Thus, it cannot be excluded that
232 relation between these two variables is caused by a third factor. The causality may be bidirectional:

233 persons with higher levels of education, lower BMI and non-smoking³⁴ may be more likely to participate
234 and persist in LTPA, which, in turn, improves resources to reduce the amount of TV-time. On the other
235 hand, it is possible that each of these factors may explain directly or indirectly the reduction of TV-time
236 among women who engage in regular LTPA.

237
238 The relationship between TV-time and physical activity is also complicated in the light of their joint
239 effect on health. Evidence shows that MVPA may eliminate the increased risk of death associated with
240 high total sitting time, and attenuates the risk associated with high TV-time.³⁵ On the other hand, even if
241 adults meet the public health guidelines for physical activity, but also sit for longer periods of time
242 without breaks, their metabolic health may be compromised.³⁶ In our study, the consistently very high
243 TV-time class accounted for only a small portion of the sample (1.5%), but it is potentially important,
244 since these subjects are characterized by high sitting time. Thus, future studies should seek to replicate the
245 results in health domains.

246 247 **Strengths and Limitations**

248 To our knowledge, this was the first study to identify TV-time trajectories from young adulthood to
249 middle age and to study their association with LTPA trajectories. Our study has several strengths,
250 including the long follow-up time, large sample size consisting of six age cohorts, and recruitment of
251 subjects throughout Finland. However, a few limitations should be acknowledged. LTPA and TV-time
252 were self-reported and measured only in leisure time and no other sedentary behavior types apart from
253 TV-time were considered. The findings are based on the data in the genetically homogeneous Finnish
254 adults and may not generalize well to other populations, especially those from low-income countries or
255 different ethnic groups.

256
257 The statistical analyses used for identifying trajectories have certain strengths. Since the association
258 between LTPA and TV-time was modelled via latent profile analysis, the uncertainty in class membership

259 was taken into account in the analysis. Another strength is that trajectory modeling is data driven,
260 meaning that it is based on objective model fit indicators for identifying the optimal number of latent
261 classes.³⁷ However, the selection of the number of classes was partly based on interpretability and class
262 sizes because the latent profile analysis with a four-class solution for LTPA could not be conducted due to
263 the small class size of very highly active participants. This led to the selection of the three-class solution
264 for LTPA, which might be a source of bias: the proportion of participants reporting moderate levels of
265 LTPA increased, while participation levels on longitudinal changes in LTPA attenuated or disappeared.
266 This is similar to the situation in TV-time, where only very few participants reported changes in TV-time.
267 Although these results may seem surprising, it is essential that some participants may increase or decrease
268 their LTPA or TV-time 10 years later, but their original behaviors have not changed enough to move
269 towards another trajectory. The limitation of trajectory modeling is that no participant perfectly follows
270 the identified trajectories: each trajectory is a mean description of the behavior of the subgroup where
271 individuals behave as similar as possible within the subgroup while differing from the other subgroups.³⁸

273 **Conclusions**

274 Our study represents relatively stable LTPA and TV-time trajectory classes in adults after 10 years of
275 follow-up. The inverse association between persistently high LTPA and excessive TV-time was observed
276 only in women after adjustment for education, BMI and smoking. We suggest that maintaining high level
277 of LTPA is accompanied by less television viewing over time for women but not for men. Future studies
278 should confirm these findings with objective monitoring devices, and the predictors, correlates and health
279 outcomes of the class memberships should be taken into account.

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References

1. Owen N, Healy GH, Matthews CE, Dunstan DW. Too much sitting: the population-health science of sedentary behavior. *Exerc Sport Sci Rev.* 2010;38(3):105-113. doi:10.1097/JES.0b013e3181e373a2
2. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) – Terminology consensus project process and outcome. *International J Behav Nutr Phys Act.* 2017;14:75. doi:10.1186/s12966-017-0525-8
3. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: the population health science of sedentary behavior. *Exerc Sport Sci Rev.* 2010;38(3):105-113. doi:10.1097/JES.0b013e3181e373a2
4. Sandell L. Television viewing in Finland 2016. Finnpanel: TV year 2017 press event. 2017.
5. Basterra-Gortari FJ, Bes-Rastrollo M, Gea A, Nunez-Cordoba JM, Toledo E, Martinez-Gonzalez MA. Television viewing, computer use, time driving and all-cause mortality: the SUN cohort. *J Am Heart Assoc.* 2014;3(3):e000864. doi:10.1161/JAHA.114.000864
6. Kim Y, Wilkens LR, Park S, Goodman MT, Monroe KR, Kolonel LN. Association between various sedentary behaviours and all-cause, cardiovascular disease and cancer mortality: the Multiethnic Cohort Study. *Int J Epidemiol.* 2013;42(4):1040-1056. doi:10.1093/ije/dyt108

- 311 7. Keadle SK, Moore SC, Sampson JN, Xiao Q, Albanes D, Matthews CE. Causes of Death
312 Associated with Prolonged TV Viewing: NIH-AARP Diet and Health Study. *Am J Prev Med.*
313 2015;49(6):811-821. doi:10.1016/j.amepre.2015.05.023
- 314 8. Reiner M, Niermann C, Jekauc D, Woll A. Long-term health benefits of physical activity – a
315 systematic review of longitudinal studies. *BMC Public Health.* 2013;13(813).
- 316 9. Mansoubi M, Pearson N, Biddle SJH, Clemes S. The relationship between sedentary behaviour and
317 physical activity in adults: A systematic review. *Prev Med (Baltim).* 2014;69:28-35.
318 doi:10.1016/j.ypped.2014.08.028
- 319 10. Sugiyama T, Salmon J, Dunstan DW, Bauman AE, Owen N. Neighborhood Walkability and TV
320 Viewing Time Among Australian Adults. *Am J Prev Med.* 2007;33(6):444-449.
321 doi:10.1016/j.amepre.2007.07.035
- 322 11. Sugiyama T, Healy GN, Dunstan DW, Salmon J, Neville O. Joint associations of multiple leisure-
323 time sedentary behaviours and physical activity with obesity in Australian adults. *Int J Behav Nutr*
324 *Phys Act.* 2008;5(35). doi:doi:10.1186/1479- 5868-5-35
- 325 12. Lakerveld J, Dunstan D, Bot S, et al. Abdominal obesity , TV-viewing time and prospective
326 declines in physical activity. *Prev Med (Baltim).* 2011;53(4-5):299-302.
327 doi:10.1016/j.ypped.2011.07.012
- 328 13. Kwon S, Janz KF, Letuchy EM, Burns TL, Levy SM. Developmental trajectories of physical
329 activity, sports, and television viewing during childhood to young adulthood: Iowa Bone
330 Development Study. *JAMA Pediatr.* 2015;169(7):666-672. doi:10.1001/jamapediatrics.2015.0327
- 331 14. Kwon S, Lee J, Carnethon MR. Developmental trajectories of physical activity and television
332 viewing during adolescence among girls: National Growth and Health Cohort Study. *BMC Public*
333 *Health.* 2015;15(1):667. doi:10.1186/s12889-015-2043-4
- 334 15. Nagin DS. *Group-Based Modeling of Development.* Cambridge Massachusetts: Harvard
335 University Press.; 2005.
- 336 16. Raitakari OT, Juonala M, Rönnemaa T, et al. Cohort profile: The cardiovascular risk in young

- 337 Finns study. *Int J Epidemiol.* 2008;37(6):1220-1226. doi:10.1093/ije/dym225
- 338 17. Yang X, Kankaanpää A, Biddle SJH, et al. Tracking of television viewing time during adulthood:
339 The Young Finns Study. *Med Sci Sports Exerc.* 2017;49(1):71-77.
340 doi:10.1249/MSS.0000000000001072
- 341 18. Telama R, Yang X, Leskinen E, et al. Tracking of physical activity from early childhood through
342 youth into adulthood. *Med Sci Sport Exerc.* 2014;46(5):955-962.
343 doi:10.1249/MSS.0000000000000181
- 344 19. Telama R, Yang X, Viikari J, Välimäki I, Wanne O, Raitakari O. Physical activity from childhood
345 to adulthood: a 21-year tracking study. *Am J Prev Med.* 2005;28(3):267-273.
346 doi:10.1016/j.amepre.2004.12.003
- 347 20. Hirvensalo M, Magnussen CG, Yang X, Telama R, Heinonen I. Convergent validity of a physical
348 activity questionnaire against objectively measured physical activity in adults : the cardiovascular
349 risk in young Finns study. *Adv Phys Educ.* 2017;7:457-472. doi:10.4236/ape.2017.74038
- 350 21. Helajärvi H, Rosenström T, Pahkala K, et al. Exploring causality between TV viewing and weight
351 change in young and middle-aged adults. The cardiovascular risk in young Finns study. *PLoS One.*
352 2014;9(7):e101860. doi:10.1371/journal.pone.0101860
- 353 22. Muthén LK, Muthén BO. *Mplus User's Guide (1998-2015)*. 7th ed. Los Angeles, CA: Muthén &
354 Muthén; 2015.
- 355 23. Muthén BO, Asparouhov T. LTA in Mplus: Transition probabilities influenced by covariates.
356 Mplus web notes. <https://www.statmodel.com/examples/LTAwebnote.pdf>. Published 2011.
357 Accessed April 24, 2019.
- 358 24. Hallal PC, Andersen LB, Bull FC, et al. Global physical activity levels: Surveillance progress,
359 pitfalls, and prospects. *Lancet.* 2012;380(9838):247-257. doi:10.1016/S0140-6736(12)60646-1
- 360 25. Laddu D, Rana J, Murillo R, et al. 25-year physical activity trajectories and development of
361 subclinical coronary artery disease as measured by coronary artery calcium: the coronary artery
362 risk development in young adults (CARDIA) study. *Mayo Clin Proc.* 2017;92(11):1660-1670.

- 363 26. Barnett TA, Gauvin L, Craig CL, Katzmarzyk PT. Distinct trajectories of leisure time physical
364 activity and predictors of trajectory class membership: a 22 year cohort study. *Int J Behav Nutr*
365 *Phys Act.* 2008;5(1):57. doi:10.1186/1479-5868-5-57
- 366 27. Lounassalo I, Salin K, Kankaanpää A, et al. Distinct trajectories of physical activity and related
367 factors during the life course in the general population : a systematic review. *BMC Public Health.*
368 2019;19(271):1-12. doi:https://doi.org/10.1186/s12889-019-6513-y
- 369 28. Sandell L. Television viewing in Finland 2015. Finnpanel: TV year 2015 press event.
370 www.finnpanel.fi. Published 2016. Accessed April 24, 2019.
- 371 29. McVeigh J, Smith A, Howie E, Straker L. Trajectories of television watching from childhood to
372 early adulthood and their association with body composition and mental health outcomes in young
373 adults. *PLoS One.* 2016;11(4):1-12. doi:10.1371/journal.pone.0152879
- 374 30. Burton NW, Khan A, Brown WJ, Turrell G. The association between sedentary leisure and
375 physical activity in middle-aged adults. *Br J Sports Med.* 2012;46(10):747-752.
376 doi:10.1136/bjism.2010.081430
- 377 31. Sugiyama T, Healy GN, Dunstan DW, Salmon J, Owen N. Is television viewing time a marker of a
378 broader pattern of sedentary behavior? *Ann Behav Med.* 2008;35(2):245-250. doi:10.1007/s12160-
379 008-9017-z
- 380 32. Olson JS, Hummer RA, Harris KM. Gender and Health Behavior Clustering among U.S. Young
381 Adults. *Biodemography Soc Biol.* 2017;63(1):3-20. doi:10.1080/19485565.2016.1262238
- 382 33. Molanorouzi K, Khoo S, Morris T. Motives for adult participation in physical activity: type of
383 activity, age, and gender. *BMC Public Health.* 2015;15(1):66. doi:10.1186/s12889-015-1429-7
- 384 34. Rovio SP, Yang X, Kankaanpää A, et al. Longitudinal physical activity trajectories from childhood
385 to adulthood and their determinants: The Young Finns Study. *Scand J Med Sci Sports.*
386 2018;28(3):1073-1083. doi:10.1111/sms.12988
- 387 35. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even
388 eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis

389 of data from more than 1 million men and women. *Lancet*. 2016;388(10051):1302-1310.

390 doi:10.1016/S0140-6736(16)30370-1

- 391 36. Dunstan DW, Salmon J, Owen N, et al. Associations of TV viewing and physical activity with the
392 metabolic syndrome in Australian adults. *Diabetologia*. 2005;48(11):2254-2261.

393 doi:10.1007/s00125-005-1963-4

- 394 37. Twisk J, Hoekstra T. Classifying developmental trajectories over time should be done with great
395 caution: A comparison between methods. *J Clin Epidemiol*. 2012;65(10):1078-1087.

396 doi:10.1016/j.jclinepi.2012.04.010

- 397 38. Muthén B, Muthén LK. Integrating person-centered and variable-centered analyses: growth
398 mixture modeling with latent trajectory classes. *Alcohol Clin Exp Res*. 2000;24(6):882-891.

399 doi:10.1111/j.1530-0277.2000.tb02070.x

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401 Legend of Figure 1. Latent transition probabilities of television viewing time trajectories conditional to
402 leisure-time physical activity trajectories adjusted for age for men (A) and women (B).