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Year: 2019

Version: Accepted version (Final draft)

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 study[12]) 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

27 linkages between LTPA and TV-time trajectory classes, and 3) to examine gender differences in such

28 associations with taking into account age, education, body mass index (BMI), and smoking.

29

30 **Methods**

31 **Participants**

32 The Cardiovascular Risk in Young Finns Study (YFS) is an ongoing longitudinal population-based study

33 consisting of six cohorts born in 1962, 1965, 1968, 1971, 1974 and 1977. The sample of healthy children

34 and adolescents, aged 3, 6, 9, 12, 15, and 18 years, were randomly selected in 1980 from the five Finnish

35 university cities with medical schools (Helsinki, Kuopio, Oulu, Tampere and Turku) and their

36 surrounding communities ($N = 3596$, 83.0% of those who were first invited). The representativeness of

37 study participants has been tested in 2001 by comparing their baseline (1980) characteristics to subjects

38 lost to follow-up.[16] The results showed participants to be older and more often women than subjects lost

39 to follow-up. However, no significant differences were observed in LTPA or TV-time between

40 participants and dropouts.[17,18] The detailed description of the YFS, reasons for non-participation at

41 follow-ups, and the characteristics of the participants have been reported elsewhere.[16]

42

43 For the present study, we chose 2001 as the baseline because that was the year when the self-reported TV-

44 time was collected for the first time from all six cohorts. The participants were ages 24–39 years in 2001,

45 and hence, 34-49 years in 2011. Those with missing information on both LTPA and TV-time variables

46 were excluded. Complete data on all variables were available for 2934 healthy adults (men, 46.0%). The

47 study protocol was reviewed and approved by the ethics committees of each of the five participating

48 universities. The informed consent of all subjects was obtained in accordance with the Helsinki

49 Declaration.[16]

50

51 **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×weekday)+(2×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 (m^2). 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.

116

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.

155

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.

173

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 alone[25] 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:

11

233   persons with higher levels of education, lower BMI and non-smoking[34] 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]

272

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.

280

293

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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).