



OPEN Investigation of dog ownership and physical activity on weekdays and weekends using longitudinal data from the SOEP Cohort

Yu TANIGUCHI^{1,2✉}, Tomoko IKEUCHI³, Markus M. Grabka⁴ & Jongsay Yong²

This study examines the association between dog ownership over a period of 5 years (always, sometimes and no ownership) with physical activity on weekdays and weekends over a period of 6 years using the nationally representative German Socio-Economic Panel. Participants were asked if they had any pets and how many hours they spend on sports, fitness, and exercise. We hypothesized that the length of dog ownership may have different effects on the physical activity of the owner. Overall, 15,240 participants completed the questionnaire on dog ownership in both 2011 and 2016, and reported their physical activity levels at least once between 2013 and 2018. Generalized estimating equation models showed that, compared to no ownership, always dog ownership was associated with higher physical activity on weekdays (Coefficient = 0.106, Standard Error: SE = 0.027, $P < 0.001$) and weekends (Coefficient = 0.121, SE = 0.033, $P < 0.001$) respectively, after controlling for related socio-demographic, physical, and psychological factors during the 6-year follow-up period. During the same follow-up period, sometimes dog ownership had no clear association with physical activity on both weekdays (Coefficient = -0.012, SE = 0.033, $P = 0.706$) and weekends (Coefficient = 0.049, SE = 0.039, $P = 0.209$) compared to no ownership. This study showed for the first time that longer dog ownership is associated with higher physical activity on both weekdays and weekends. Future research will be needed to investigate whether any causal relationships underlie the association.

Keywords Dog, Animals, Physical activity, SOEP

The World Health Organization guidelines on physical activity and sedentary behavior provide public health recommendations for all population groups. It is well known that regular physical activity helps prevent and manage adverse health outcomes. However, 1 in 4 adults do not meet the global recommended levels of physical activity¹. A 2013 review article based on 29 studies showed some directional evidence of a causal relationship between dog ownership and physical activity². Previous studies have also shown that dog ownership has a positive effect on the health of owners^{2–15}, and the mechanism underlying the relationship between dog ownership and health outcomes might be explained by the increased physical activity^{8,9}.

The association between dog ownership and the owner's physical activity has been reported in cross-sectional studies^{16–20} and longitudinal studies^{21–24}. Previous cross-sectional studies reported that dog ownership was associated with more recreational walking and greater likelihood of attaining physical activity guidelines among mainly middle-aged or older adults in the UK¹⁶. In the US, dog ownership among adolescents was found to be associated with more physical activity¹⁸, and similarly for adults in German¹⁷. Adult dog ownership in US is associated with more walking and leisure-time physical activity¹⁹. Similarly in Japan, dog walker reported engaging in more minutes per week of moderate-to-vigorous physical activity among older adults²⁰. One of the first longitudinal studies in this field showed that dog owners increased the number of weekly walks they took ten months after acquiring a dog²¹. Other previous longitudinal studies reported that dog acquisition led to an increase in walking in Australia²², longer walking times and fewer sedentary events in the UK among older

¹Japan Environment and Children's Study Programme Office, National Institute for Environmental Studies, 16-2 Onogawa, 305-8506 Tsukuba, Tsukuba, Ibaraki, Japan. ²Melbourne Institute of Applied Economic and Social Research, The University of Melbourne, Faculty of Business and Economics Building, 111 Barry Street, 3010 Melbourne, VIC, Australia. ³Research Team for Human Care, Tokyo Metropolitan Institute for Geriatrics and Gerontology (TMIG), 35-2 Sakae-cho, Itabashi-ku, 173-0015 Tokyo, Japan. ⁴German Institute for Economic Research / SOEP, Mohrenstraße 58, 10117 Berlin, Germany. ✉email: taniguchi.yu@nies.go.jp

adults²³, and it was reported that dog walkers were more likely to achieve recommended walking levels in the US²⁴.

Accumulated evidence suggests that the experience of owning a dog influences owners' physical activity. However, the association of the length of dog ownership with physical activity levels has not been examined in the previous studies. We hypothesized that the length of dog ownership may have different effects on the physical activity of the owner. A recently published study examined the effects of dog ownership, dog acquisition, and dog loss on children's movement behaviors over a three-year period from preschool to fulltime school²⁵. However, available evidence to cover a wider age range from children to older adults is still lacking. Moreover, physical activity on weekdays and weekends may differ depending on individuals' employment and lifestyle characteristics, yet the difference has yet to be clarified in the literature.

This study reports results from a prospective dynamic cohort study in Germany. The objective is to examine the association of the length of dog ownership over a 5-year period (always, sometimes, and no ownership) with physical activity on weekdays and weekends over a 6-year follow-up period. This study provides new insights into the mechanism underlying human-animal interactions and health outcomes.

Results

Sample characteristics

Data from the baseline survey of 15,240 participants showed that the mean (Standard Deviation: SD) age of participants was 44.3 (21.9) years, and that 52.2% were women. 87.0% had siblings, the mean (SD) number of household members was 2.8 (1.3), and 56.1% owned a house or apartment. Over a 5-year period (2011 and 2016), 1,622 (10.6%) participants were always dog owners, 1,376 (9.0%) were sometimes dog owners, and the remaining 12,242 (80.3%) were non-dog owners (Table 1). Compared with non-dog owners, those in always dog ownership were younger, had larger household size, more likely to be homeowners, had higher equivalised income, employed, smoked, less likely to have high blood pressure and arthritis, and had lower Mental Component Score (MCS) score.

Main analyses for the associations of dog ownerships with physical activity on weekdays and weekends

During the period under study, always dog owners had higher levels of physical activity on weekdays and weekends as compared to sometimes and no ownership groups (Figs. 1 and 2). Sometimes and no dog ownership groups showed similar mean values of physical activity on weekdays and weekends. Results from GEE models (Table 2) showed that always dog owners had higher physical activity on weekdays (Coefficient = 0.106, Standard Error: SE = 0.027, $P < 0.001$) and weekends (Coefficient = 0.121, SE = 0.033, $P < 0.001$) as compared to the non-dog owners in the fully adjusted models which include socio-demographic, physical, and psychological variables. No statistically significant differences were found between sometimes and no dog ownership groups on weekdays (Coefficient = -0.012, SE = 0.033, $P = 0.706$) and weekends (Coefficient = 0.049, SE = 0.039, $P = 0.209$).

Causal relationship between dog ownership and physical activity

To address the selection into dog ownership, an instrumental variable model is estimated using birth order as the exogenous instrument. Results showed that always dog ownership had negative effects on physical activity in weekdays (Coefficient = -1.000, SE = 0.339, $P = 0.003$), as compared to no ownership (Table 3). The minimum eigenvalue statistic was 23.1, indicating that the instrument was reasonable. For physical activity during weekends, no statistically significant effect was found (Coefficient = -0.393, SE = 0.355, $P = 0.268$) and minimum eigenvalue statistic was 12.6, indicating a potential weak instrument problem.

Discussion

Based on current evidence^{16–25}, we hypothesized that the length of dog ownership may have different effects on the physical activity of owners. Using a nationally representative prospective cohort data, this study found that always dog ownership was associated with higher physical activity compared to no owners after controlling for socio-demographic, physical, and psychological factors during a 5-year period. The associations were shown to apply to both weekdays and weekends physical activity.

This study further showed that there was no significant difference in physical activity among sometimes owners compared to non-dog owners. Our findings are consistent with previous research²⁵ and suggest that longer exposure to dog ownership increases owners' physical activity levels. This study was the first to show that longer dog ownership was associated with higher physical activity on both weekdays and weekends, after adjusting for socio-demographic factors including employment status.

Tentative results of the causal analysis in this study showed that always dog ownership had a negative effect for weekdays physical activity. After accounting for the non-random (self-)selection into dog ownership using birth order as an exogenous instrument, always dog owners were found to be physically less active on weekdays than non-owners. The result could be indicative of a strong selection effect into dog ownership – individuals who were more physically active (or more interested in physical activity) were more likely to choose to own a dog. After accounting for this selection effect, dog ownership was found to reduce physical activity levels of these individuals during weekdays. No such effects were found for weekend physical activity. The results are tentative due to a potential weak instrument concern. In addition, it is unclear why the results were inconsistent on weekdays and weekends. Future research will be needed to examine in detail the causal relationships.

This study has several strengths. First, the SOEP survey is a large-scale representative dynamic cohort study in Germany. The data enable us to classify the length of dog ownership into always, sometimes, and no ownership over a 5-year period. The SOEP data further enable us to separately examine the relationship between

Variable	Dog ownership			P-value
	Always (n = 1622)	sometimes (n = 1376)	No ownership (n = 12242)	
SOCIO-DEMOGRAPHICS				
Age				P < 0.001
mean (SD)	41.2 (20.4)	38.5 (21.3)	45.4 (22.0)	
Sex (% female)	53.3	53.0	51.9	P = 0.493
Birth order (% siblings)	86.2	88.0	87.0	P = 0.416
Household members				P < 0.001
mean (SD)	3.2 (1.3)	3.2 (1.4)	2.7 (1.3)	
House type (%)				P < 0.001
Owner	70.3	56.3	54.2	
Main tenant	28.7	42.7	44.1	
Sub-tenant	1.1	1.0	1.5	
Education (%)				P < 0.001
In school	0.2	0.7	0.3	
Primary education	3.6	3.9	2.3	
Lower secondary education	9.4	11.0	9.4	
Upper secondary education	52.2	56.2	49.4	
Post-secondary non-tertiary education	7.1	5.9	6.3	
Short-cycle tertiary education	5.2	4.3	4.7	
Bachelors or equivalent level	16.4	12.2	19.1	
Masters or equivalent level	5.6	5.6	8.1	
Doctoral or equivalent level	0.2	0.3	0.5	
Annual post-government equivalised income (EUR)				P < 0.001
mean (SD)	24,173 (15501)	21,398 (12176)	23,811 (16792)	
Employment status (% yes)	65.4	65.9	57.3	P < 0.001
Smoking status (% yes)	28.9	34.0	22.4	P < 0.001
Drinking status (% yes)				P = 0.090
Everyday	7.5	8.4	8.2	
4–6 times a week	9.3	7.7	7.9	
2–3 times a week	19.4	17.2	19.7	
2–4 times a month	22.4	21.0	23.5	
Less than once a month	23.0	26.3	22.7	P = 0.329
Never	18.3	19.5	18.1	
PHYSICAL VARIABLES				
Stroke (Yes %)	1.7	1.6	1.8	P = 0.911
High blood pressure (Yes %)	24.2	23.1	26.3	P = 0.033
Diabetes (Yes %)	6.9	7.7	8.1	P = 0.323
Cancer (Yes %)	4.3	3.8	4.8	P = 0.268
Psychiatric problems (Yes %)	7.4	6.8	6.2	P = 0.272
Arthritis (Yes %)	17.8	17.6	20.6	P = 0.008
Disability (Yes %)	13.7	13.8	13.4	P = 0.928
PCS (score)				P = 0.756
mean	49.0	48.7	48.8	
SE	9.8	9.9	9.9	
PSYCHOLOGICAL VARIABLES				
Satisfaction with health				P = 0.225
mean (SD)	6.5 (2.3)	6.5 (2.2)	6.6 (2.2)	
Self-rated health (%)				P = 0.075
Excellent	8.7	9.2	9.0	
Very good	40.6	40.1	40.0	
Good	33.5	31.5	34.3	
Fair	12.6	14.9	13.6	
Poor	4.7	4.3	3.2	
MCS (score)				P = 0.002
mean (SD)	49.9 (9.8)	49.6 (10.0)	50.5 (9.8)	

Table 1. Relationship between socio-demographic, physical, and psychological factors and dog ownership. Source: SOEPv38eu. Unweighted results. Numerical data are shown as mean and standard deviation (SD), and categorical data are shown in proportion. P-values were calculated by the analysis-of-variance for numerical data and chi-square test for categorical data. PCS Physical Component Scale, MSC Mental Component Scale.

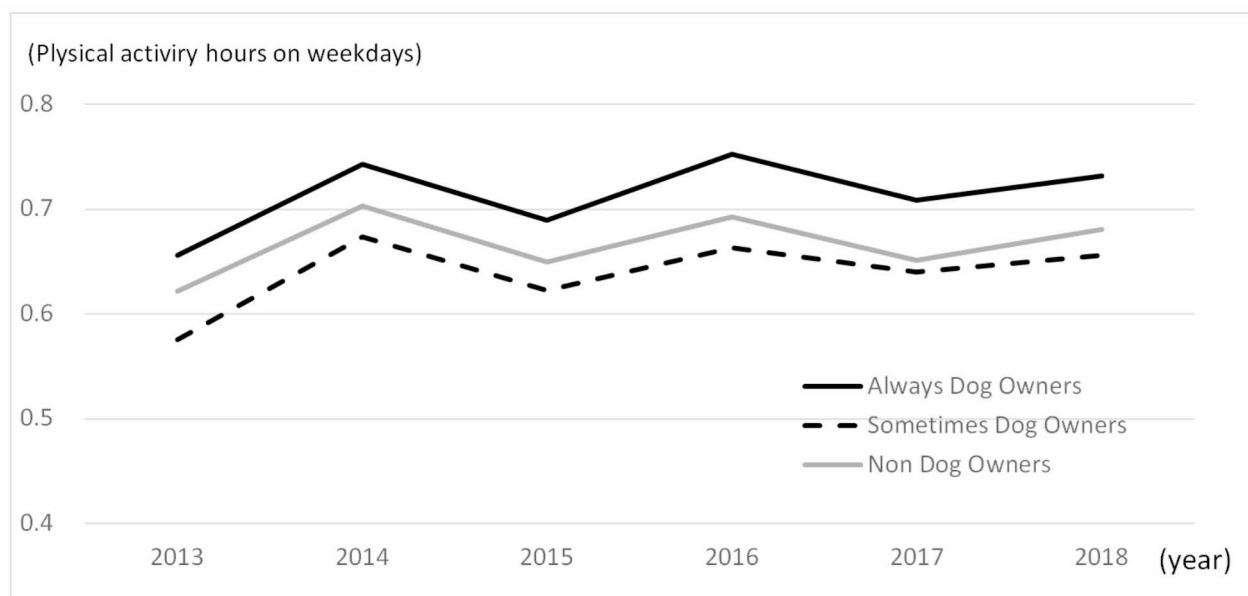


Fig. 1. Mean physical activity hours on weekdays by dog ownership. Source: SOEPv38eu. Mean hours of sports, fitness, and exercise on an average weekday among dog ownership groups over a 5-year period.

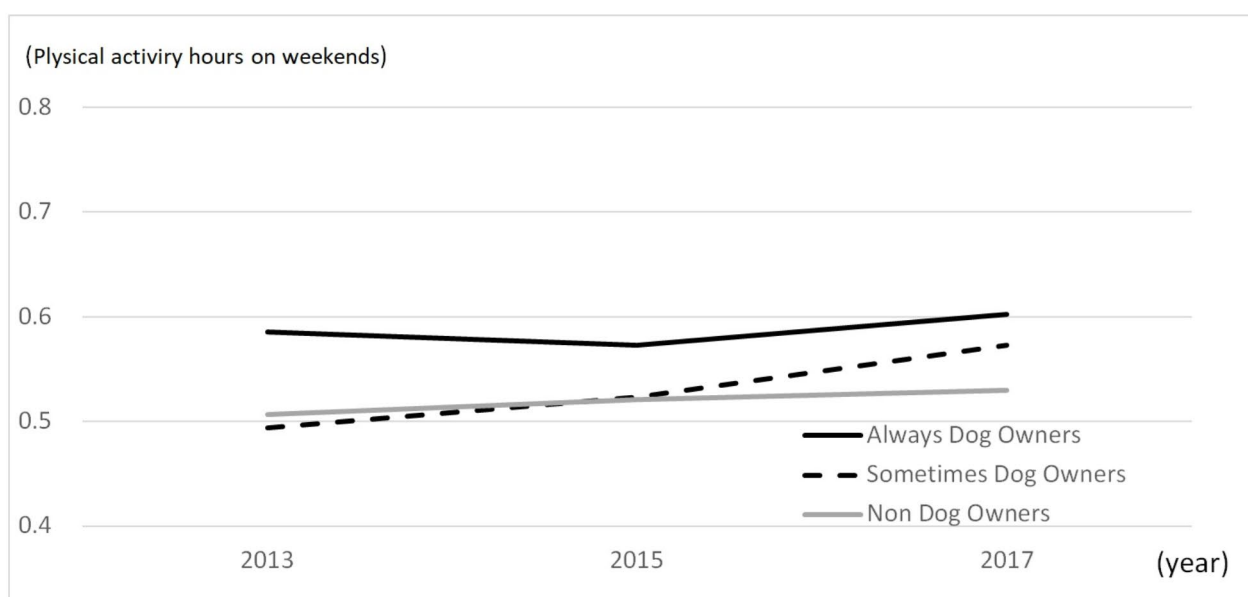


Fig. 2. Mean physical activity hours on weekends by dog ownership. Source: SOEPv38eu. Mean hours of sports, fitness, and exercise on an average weekend among dog ownership groups over a 5-year period.

	Physical activity on weekdays				Physical activity on weekends											
	Model-1 (obs = 71182)				Model-2 (obs = 55856)				Model-1 (obs = 35909)				Model-2 (obs = 28209)			
	Coefficient	SE	P-value		Coefficient	SE	P-value		Coefficient	SE	P-value		Coefficient	SE	P-value	
Sometimes dog ownership	- 0.045	0.028	0.109		-0.012	0.033	0.706		- 0.012	0.034	0.728		0.049	0.039	0.209	
Always dog ownership	0.070	0.023	<0.001		0.106	0.027	<0.001		0.104	0.029	<0.001		0.121	0.033	<0.001	
Source: SOEPv38eu.																
SE, Standard Error. Reference group was non-dog ownership.																
Generalized estimating equation (GEE) were run in Model-1: follow-up year, age, sex, household members, and equivalised income. Model-2 added house type, education, employ status, smoking habit, drinking habit, disability, satisfaction with health, self-rated health, stroke, high blood pressure, diabetes, cancer, psychiatric problems, arthritis, Physical Component Scale, and Mental Component Scale.																

Table 2. Associations of dog ownership with physical activity on weekdays or weekends.

	Physical activity on weekdays					Physical activity on weekends				
	Model-1			Model-2		Model-1			Model-2	
	Coefficient	SE	P-value	Coefficient	P-value	Coefficient	SE	P-value	Coefficient	P-value
Sometimes dog ownership	− 5.591	3.874	0.149	− 10.988	0.279	− 2.815	3.291	0.392	− 0.4736	5.819
Always dog ownership	− 0.575	0.225	0.011	− 1.000	0.003	− 0.169	0.257	0.511	− 0.393	0.355
Source: SOEPv38eu.										
SE, Standard Error. Reference group was non-dog ownership.										
Instrumental variables with birth order as third variable were run in Model-1: follow-up year, age, sex, household members, and equivalised income. Model-2 added house type, education, employ status, smoking habit, drinking habit, disability, satisfaction with health, self-rated health, stroke, high blood pressure, diabetes, cancer, psychiatric problems, arthritis, Physical Component Scales, and Mental Component Scale.										

Table 3. Causal relationship of dog ownership with physical activity on weekdays or weekends.

dog ownership and physical activity in weekdays and weekends. Second, the SOEP data enable us to include important covariates in examining the association of dog ownership with physical activity. We were able to capture relevant socio-demographic characteristics of dog owners and to the extent that was broadly consistent with previous studies^{26,27}.

This study also has some limitations. First, several important dimensions of pet ownership could not be included in this study, such as the degree of attachment to a pet. Attachment is known to influence psychological aspects^{28,29} of pet ownership, and a deeply attached owner-pet relationship might play a key role in affecting health and wellbeing of owners. Future research is needed to clarify the mechanism by identifying confounding factors, such as how the degree of attachment and primary caretaking interact with dog ownership and physical activity. The investigation could also be improved with the inclusion of further variables, such as the age of the dog. As has already been shown, the age of the dog is related to the intensity of physical activity, with owners of older dogs tend to walk less¹⁹. Second, several key data items used as covariates were collected in different waves of the survey. Future studies should be undertaken to assess whether the timing difference affects our findings. Third, the classification of dog ownership into always, sometimes or no ownership is subject to measurement errors. Since in the SOEP survey, questions on pet ownership were asked every 5 years, it is possible that ownership status may be disrupted during the 5-year period.

In summary, this prospective study revealed that, compared to no ownership, always dog ownership was associated with higher physical activity on weekdays (Coefficient = 0.106, SE = 0.027, $P < 0.001$) and weekends (coefficient = 0.121 SE = 0.033, $P < 0.01$) respectively, after controlling for relevant socio-demographic, physical, and psychological factors during the 6-year follow-up period in Germany. In contrast, sometimes dog ownership had no clear association with physical activity as compared to no ownership. Causal analysis provides indicative evidence that selection into dog ownership is a potential issue, noting however that results were inconsistent for physical activity on weekdays and weekends. Further research will be needed to examine the casual relationship in greater detail.

Methods

Study population

The German Socio-Economic Panel (SOEP) survey is the representative longitudinal dynamic cohort study of individuals living in private households in Germany³⁰. The samples were drawn either using a random route method or based on drawings from residents' registration offices. The survey is organized by the German Institute for Economic Research (DIW Berlin) and is funded by the German Federal Government and the State of Berlin. SOEP started in 1984 and is conducted every year. Currently it covers approximately 30,000 people in 15,000 households. An advantage of the SOEP is the rich and diverse information it contains at individual and household levels on income, living conditions, employment, health status, household composition, education, social capital, and satisfaction^{31,32}. The dataset used in the present study is SOEP-CORE.v38. The SOEP study was approved by the Institutional Review Board of the SOEP. This study was a secondary analysis of anonymized data, and therefore required no ethics approval. Participants gave their informed consent prior to data collection. Detailed information on ethical clearance and informed consent given by the participants related to the SOEP can be found on the website of the German Institute for Economic Research (DIW), Berlin (<https://www.diw.de/soep>). The study was performed in accordance with all relevant guidelines and regulations in relation to the use of SOEP data.

Definition of pet ownership

Participants were asked if they had any pet in 2011 and 2016. Those with current pet ownership were asked to indicate the pet species, i.e., dog, cat, rabbit, guinea pig/hamster/mouse, bird, fish, horse/pony, or other pets. These responses were used to classify dog ownership as "always", "sometimes", and "no ownership" over the 5-year period. Always ownership was defined as those who had dogs in both 2011 and 2016. Sometimes ownership was defined as those who had dogs either in 2011 or 2016 but not both, and no ownership was defined as those who did not have dogs in both 2011 and 2016.

Definition of physical activity

Participants were asked, every year from 2013 to 2018, on how many hours they spend on sports, fitness, and exercise on an average weekday. Moreover, they were also asked how many hours they spend on an average Saturday and Sunday, respectively, in 2013, 2015, and 2017. For all questions, participants responded by stating the number of hours spent as numerical values. In this study, physical activity during weekdays was assessed based on participants' responses over the 6-year period (2013 to 2018) and physical activity on Saturday and Sunday was combined and evaluated as physical activity levels on weekends over the 5-year period (2013 to 2017).

Socio-demographic, physical, and psychological variables

Socio-demographic variables included age, sex, birth order, household members, house type (owner, main tenant, or sub-tenant), education (in school, primary education, lower secondary education, upper secondary education, post-secondary non-tertiary education, short-cycle tertiary education, bachelors or equivalent level, masters or equivalent level, or doctoral or equivalent level), annual post-government equalised income, employment status (yes or no), and smoking (yes or no) and drinking habit (everyday, 4–6 times a week, 2–3 times a week, 2–4 times a month, less than once a month, or never). Physical variables were history of chronic disease (ever diagnosed a stroke, high blood pressure, diabetes, cancer, psychiatric problems or arthritis), disability, and Physical Component Score (PCS). Psychological variables were satisfaction with health (0 to 10 points), self-rated health (excellent, very good, good, fair, or poor), and Mental Component Score (MCS). PCS

and MCS were calculated by the Short Form 12 (SOEP-SF-12) that includes 12 items or questions that assess functional health and well-being of an individual³³. Since not all covariates were collected in all survey years, information from 2012 was used for PCS and MCS, 2014 for smoking habits and 2016 for drinking habits, while all other variables refer to data collected in 2011. Further, not all covariates were included in all statistical models. Covariates were added in groups in a step-wise manner to build successively more comprehensive models. Covariates were selected based on a priori theoretical reasoning on how likely they would correlate with the ability (e.g., physical health, employment and income variables) or tendency (e.g., psychological health variables) to engage in physical activity.

Eligibility criteria

To be eligible for the study, individuals must have completed the questionnaire on dog ownership in both 2011 and 2016, and must have completed the physical activity measures at least once from 2013 to 2018. A total of 15,240 participants were included in this study. Observations with missing values were excluded from the analysis.

The data file of the SOEP is made available for this research by the German Institute for Economic Research (DIW) at doi: <https://doi.org/10.5684/soep.v38eu>. The use of anonymized SOEP data is subject to strict standards and only for research purposes. SOEP data are available free of charge for scientific use upon requesting a data distribution contract with DIW. This study did not require ethics approval as the analysis only used de-identified data in the form of unit record data from the SOEP Survey.

Statistical analysis

First, relationships between socio-demographic, physical, and psychological factors and the length of dog ownership were tested using chi-square tests or analysis of variance. Next, group-specific mean values of physical activity on weekdays and weekends were calculated by dog ownership status during the 5-year study period. The relationships between dog ownership status and physical activity during weekdays and weekends were modeled by generalized estimating equations (GEE). GEE models can account for the correlation of within-subject data. Follow-up years were included as covariates in the form of year dummy values. Separate GEE models were estimated for respondents in no ownership and sometimes ownership groups, and no ownership and always ownership groups, respectively. Covariates were selected by all authors based on a priori theoretical reasonings. Model-1 was adjusted for follow-up years, age, sex, household members, and equivalised income. In addition to the covariates in Model-1, Model-2 added house type, education, employment status, smoking habit, drinking habit, disability, satisfaction with health, self-rated health, stroke, high blood pressure, diabetes, cancer, psychiatric problems, arthritis, PCS, and MCS scores. Lastly, since dog ownership was not randomly assigned in the data, to identify causal relationship between dog ownership and physical activity, an instrumental variable approach with birth order as the instrument was estimated. Birth order is a potential instrument since it was likely to be correlated with dog ownership due to potential birth-order effects³⁴ on caring and responsibility. In addition, birth order should not affect physical activity directly. Covariates used in the instrumental variable model were identical to those in Model-2 (i.e., follow-up year, age, sex, household members, equivalised income, house type, education, employ status, smoking habit, drinking habit, disability, satisfaction with health, self-rated health, stroke, high blood pressure, diabetes, cancer, psychiatric problems, arthritis, PCS, and MCS scores). Statistical analyses were conducted using Stata SE (version 18; Stata Corp, College Station, TX, USA).

Data availability

This paper uses unit record data from the SOEP Survey (https://www.diw.de/en/diw_01.c.601584.en/data_access.html#c_741351).

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Author contributions

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to Y.T.

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