



Association between preschooler movement behaviours, family dog ownership, dog play and dog walking: Findings from the PLAYCE study

Hayley Christian^{a,b,*}, Elizabeth J. Wenden^{a,b}, Michelle Ng^a, Clover Maitland^{c,d}

^a Telethon Kids Institute, University of Western Australia, Perth, Australia

^b School of Population and Global Health, University of Western Australia, Perth, Australia

^c School of Human Sciences, University of Western Australia, Perth, Australia

^d Centre for Behavioural Research in Cancer, Cancer Council Victoria, Melbourne, Australia

ARTICLE INFO

Keywords:

Preschooler
Dog ownership
Physical activity
Movement behaviour

ABSTRACT

Physical inactivity in childhood is a major public health issue. Dog ownership has been widely reported to lead to greater physical activity in adults and school-aged children. We examined if dog ownership and dog-facilitated physical activity were associated with higher physical activity in preschoolers. Secondary analysis of the 'Play Spaces & Environments for Children's Physical Activity' (PLAYCE, 2015–2018) study involving 1366, 2–5-year-olds from 122 long day-care centres in Perth, Australia was conducted. Socio-demographics and movement behaviours (physical activity, screen time, sleep) were examined by dog ownership, dog play and dog walking. Dog-owning preschoolers did physical activity 8 times/week more but 6 min/day less park play than non-dog owners (all $p < 0.05$). Dog-owning preschoolers who played with their dog ≥ 3 times/week did more physical activity, outdoor play and had 16 min/day more sleep (all $p < 0.05$). For dog-owners, family dog walking ≥ 3 times/week was positively associated with preschooler physical activity, outdoor play and negatively associated with screen time (all $p < 0.05$). Our findings suggest that the physical activity-related benefits from having a family dog may be realised when preschoolers spend time playing and walking their dog. Dog walking and play, not dog ownership alone, may be an important source of physical activity for preschoolers.

1. Introduction

Regular physical activity provides benefits for preschool children (2–5 years) including cardiorespiratory fitness, healthy weight status, bone health, and better social-emotional, cognitive and motor development (Carson et al., 2017). Several countries including Australia and the World Health Organization have released 24-hour movement guidelines for the early years. (Australian Government Department of Health, 2017). They recommend preschoolers aged 3–5 years should: 1) accumulate at least 180 min of total physical activity per day including at least 60 min of moderate to vigorous physical activity; 2) have no more than 60 min of sedentary screen time per day and; 3) sleep between 10 and 13 h per day (Australian Government Department of Health, 2017). However, many children do not meet the 24-hour movement (physical activity, screen and sleep) guidelines for the early years (Cliff et al., 2017; Roman-Viñas et al., 2016).

There is evidence of the physical activity benefits of dog ownership in adults (Christian et al., 2013; Rhodes et al., 2020). There is also

evidence that dog ownership is associated with increased physical activity in school aged children (e.g., Christian et al., 2013; 2014; Martin et al., 2015). For example, children (10–12 years) with a family dog are 50% more likely to achieve the recommended level of physical activity compared with non-dog owners (Christian et al., 2013). In addition, children who walk their dog, are more likely to play in the street and yard and be independently mobile compared with children who don't walk their dog (Christian et al., 2014). However, studies involving younger preschool aged children are scarce. A recent qualitative study explored the barriers and motivators to preschoolers' playing with their dog and participating in family dog walks (Coci et al., 2022). A number of dog-specific, individual and physical environment influencing factors were identified including parents' level of attachment to their dog, parental history of dog ownership, parent modelling of safe dog play, type of play the family dog enjoys and proximity to dog- and child-friendly destinations (Coci et al., 2022). Another recent study, showed dog ownership, in particular active play with the family dog and family dog walking is associated with social-emotional developmental benefits

* Corresponding author at: Telethon Kids Institute, Perth Children's Hospital, 15 Hospital Avenue, Nedlands, Western Australia 6009, Australia.

E-mail address: hayley.christian@uwa.edu.au (H. Christian).

<https://doi.org/10.1016/j.pmedr.2022.101753>

Received 14 September 2021; Received in revised form 24 February 2022; Accepted 26 February 2022

Available online 28 February 2022

2211-3355/© 2022 Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

for preschool children (Wenden et al., 2021).

Given dog ownership is higher in households with young children (45–51%) (Christian et al., 2020), further research is required to understand the physical activity opportunities dog ownership could provide. This study investigated if family dog ownership and dog-facilitated physical activity (dog play and family dog walking) was associated with preschooler movement behaviours (physical activity, screen time and sleep).

2. Methods

2.1. Study sample

Data from 1336 children aged 2–5 years in the ‘Play Spaces and Environments for Children’s Physical Activity’ (PLAYCE) study were analysed (Christian et al., 2016). PLAYCE was an observational study of the early childhood education and care (ECEC), home and neighbourhood influences on young children’s physical activity behaviours (Christian et al., 2016). Participants were recruited from ECEC services located in metropolitan Perth, Western Australia (response rate 46%) stratified by size and socio-economic status. Children were ineligible if they attended school full-time or had a condition that prevented them engaging in physical activity. Parents provided written consent. Data were collected between 2015 and 2018. The PLAYCE study protocol and methods have been published previously (Christian et al., 2016). The University of Western Australia Human Research Ethics Committee provided approval (RA/4/1/7417).

2.2. Measures

The parent-report survey included existing reliable measures of socio-demographic characteristics (child sex, age, parent education), family pet dog ownership (yes/no), structured (planned, set times, has rules, specialised equipment) and unstructured (free, spontaneous, child decides how, what and where) physical activity (times/week), outdoor play (minutes/day), family dog walking and child-dog play (times/week), screen time (minutes/day) and sleep (hours/day) (Christian et al., 2016).

Parents reported the frequency per week their child spent doing structured and unstructured physical activities (never/rarely, less than once/week, 1–2 times/week, 3–4 times/week, 5–6 times/week, daily). Items were adapted from the Healthy Active Preschool Years Study (Hinkley et al., 2012) and included items measuring frequency of ‘playing with the dog’ and ‘walking the dog’. The reliability of these items is sound (e.g., unstructured physical activity items intraclass correlation (ICC) = 0.63; structured physical activity items ICC = 0.70) (Hinkley et al., 2012).

Minutes per day of outdoor play was measured using a validated, established tool where parents reported the amount of time (0 min; 1–15 min; 16–30 min; 31–60 min; and >60 min) across three periods of the day (wake-up time until noon; noon until 6 pm; 6 pm until bedtime) on weekdays and weekend days that their child spent playing in the yard or street around the house; at a park, playground, or outdoor recreational area; and actively indoors at home (Burdette et al., 2004). These items have previously been validated against young children’s accelerometer data ($r = 0.33, p < 0.001$) (Burdette et al., 2004).

Preschoolers wore ActiGraph GT3X + accelerometers on the hip for seven days during waking hours to measure frequency, duration and intensity of physical activity in 15-second epochs (Pate et al., 2010). Cut points (Pate et al., 2010) were used to discriminate between sedentary, light, moderate and vigorous physical activity (total physical activity: sum of light, moderate and vigorous physical activity), with a minimum of three weekdays and one weekend day (8hrs wear time/day) of valid data (Christian et al., 2016).

Unadjusted associations between dog ownership and socio-demographic factors were tested using Chi-square analyses for

categorical variables. T-tests were used to determine differences in child age and movement behaviours by dog ownership. Linear regression analyses assessed the associations between a) dog ownership, b) dog play, c) family dog walking and movement behaviour outcome variables with adjustment for socio-demographic factors (child age and gender, parent education).

3. Results

3.1. Sample characteristics

Preschoolers were on average 3.3 (SD 0.7) years old, 52% were boys,

Table 1
Characteristics of PLAYCE preschooler study cohort (Perth, Western Australia 2015–2018).

Characteristic	Total sample (n = 1,366) Mean (SD) or n (%)	Dog owners (n = 583) Mean (SD) or n (%)	Non-dog owners (n = 783) Mean (SD) or n (%)	p-value ^a
Child sex				0.76
Boys	715 (52.3)	308 (52.8)	407 (52.0)	
Girls	651 (47.7)	275 (47.2)	376 (48.0)	
Child age	3.3 (0.7)	3.3 (0.7)	3.3 (0.7)	0.52
Parent education				<0.001*
Less than secondary	66 (4.8)	38 (6.5)	28 (3.6)	
Year 12/Trade/ Diploma	513 (37.6)	263 (45.1)	250 (31.9)	
Tertiary degree	787 (57.6)	282 (48.4)	505 (64.5)	
Accelerometer wear time (min/day)	637 (64.0)	634 (59.0)	639 (68.0)	0.19
Light physical activity (min/ day)	82.7 (14.9)	83.1 (14.3)	82.4 (15.3)	0.38
Moderate/Vigorous physical activity (min/day)	80.1 (25.9)	81.3 (26.4)	79.2 (25.5)	0.14
Total physical activity (min/ day)	163 (38.0)	164 (38.0)	162 (38.0)	0.17
Sedentary (min/ day)	474 (59.0)	470 (55.0)	477 (62.0)	0.02*
Structured physical activity (times/ week) ^b	2.0 (1.3)	1.9 (1.3)	2.0 (1.3)	0.79
Unstructured physical activity (times/week)	20.4 (10.0)	25.2 (10.1)	16.8 (8.2)	<0.001*
Playing outdoors at home (mins/day)	73.9 (44.6)	76.9 (44.3)	71.6 (44.8)	0.03*
Playing outdoors at park (mins/day)	49.3 (41.2)	45.5 (40.4)	52.2 (41.6)	0.003*
Total time playing outdoors (mins/ day)	123.0 (72.0)	122 (69.0)	124 (73.0)	0.71
Screen time (mins/ day)	107 (78.0)	108 (76.0)	106 (80.0)	0.71
Sleep time (hours/ day)	11.5 (1.3)	11.4 (1.3)	11.5 (1.2)	0.11
Dog owner	583 (42.7)	–	–	
Family dog walking 2 or less times/ week	–	447 (76.7)	–	
3 or more times/ week	–	136 (23.3)	–	
Dog playing 2 or less times/ week	–	136 (23.3)	–	
3 or more times/ week	–	447 (76.7)	–	

Sample: preschoolers aged 2–5 years.

^a p-value for dog owners compared with non-dog owners; * $p < 0.05$.

^b n = 910 (375 dog owners; 535 non-dog owners. 456 children did no structured physical activity).

43% had a family dog and 58% of parents had a tertiary education (Table 1). Mean accelerometer-derived total physical activity was 163 (SD 38.0) minutes/day and sedentary time was 474 (SD 59.0) minutes/day. Parent-reported mean structured and unstructured physical activity frequency were 2.0 times/week (SD 1.3) and 20.4 times/week (SD 10.0), respectively. Average total time spent playing outdoors was 123 min/day (SD 72.0). Mean screen time was 107 (SD 78) minutes/day and preschoolers slept on average 11.5 h/day (SD 1.3). Within dog owners, 77% of preschoolers played with their dog three or more times/week and 23% went on family dog walks three or more times/week. More non-dog owning parents had a tertiary education than dog-owning parents ($p < 0.001$). There were no other socio-demographic differences by dog ownership.

3.2. Adjusted associations between dog ownership status and preschooler physical activity

Dog ownership was positively associated with preschooler unstructured physical activity frequency/week ($B = 8.2$, 95% CI: 7.3, 9.2) and negatively associated with park play minutes/day ($B = -6.1$, 95% CI: -10.5 , -1.6) (Table 2). Dog ownership was not associated with any

Table 2
Adjusted associations between dog ownership, dog play, and family dog walking and preschooler movement behaviours in PLAYCE study cohort (Perth, Western Australia 2015–2018).

	Full sample (n = 1366)	Dog-owning family sub-sample (n = 583)	
	Dog ownership ^a	Dog play ≥ 3 times/week ^b	Family dog walking ≥ 3 times/week ^c
	B (95% CI)	B (95% CI)	B (95% CI)
Accelerometer derived measures^d			
Light physical activity (mins/day)	1.2 (−0.2, 2.5)	1.6 (−0.8, 4.0)	1.0 (−1.4, 3.4)
Moderate/Vigorous physical activity (mins/day)	1.8 (−0.6, 4.3)	0.2 (−4.2, 4.5)	3.2 (−1.1, 7.6)
Total physical activity (mins/day)	3.0 (−0.4, 6.5)	1.6 (−4.4, 7.7)	4.4 (−1.7, 10.4)
Sedentary (mins/day)	−3.0 (−6.5, 0.4)	−1.6 (−7.7, 4.4)	−4.4 (−10.4, 1.7)
Parent-report measures^e			
Structured physical activity (times/week) ^f	0.0 (−0.2, 0.2)	0.4 (0.1, 0.8) **	0.5 (0.2, 0.8) **
Unstructured physical activity (times/week)	8.2 (7.3, 9.2) ***	12.5 (10.9, 14.2) ***	10.5 (8.8, 12.3) ***
Playing outdoors at home (mins/day)	4.57 (−0.3, 9.4)	30.8 (22.8, 38.9) ***	10.3 (1.9, 18.8) *
Playing outdoors at park (mins/day)	−6.1 (−10.5, −1.6) **	8.2 (0.5, 15.9) *	21.1 (13.5, 28.6) ***
Total time playing outdoors (mins/day)	−1.5 (−9.3, 6.3)	39.1 (26.2, 52.0) ***	31.4 (18.4, 44.5) ***
Screen time (mins/day)	−2.01 (−10.4, 6.4)	5.9 (−20.5, 8.6)	−16.7 (−31.3, −2.2) *
Sleep time (hours/day)	−0.1 (−0.2, 0.1)	0.3 (0.0, 0.5) *	0.2 (0.0, 0.4)

Note: Boldface indicates statistical significance (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

^a Reference group = non-owning families of preschoolers (aged 2–5 years).
^b Reference group = dog owning families who reported their preschooler (aged 2–5 years) played with the dog < 3 times/week.
^c Reference group = dog owning families who reported their preschooler (aged 2–5 years) went on family dog walks < 3 times/week.
^d Models adjusted for child age and gender, parent education and accelerometer wear time.
^e Models adjusted for child age and gender and parent education.
^f $n = 910$ (375 dog owners; 535 non-dog owners. 456 children did no structured physical activity).

other preschooler movement behaviour variables.

3.3. Adjusted associations between dog play ≥ 3 times/week and preschooler movement behaviours (dog owners only)

In dog-owning families, dog play (≥ 3 times/week) was positively associated with preschooler structured ($B = 0.4$, 95% CI: 0.1, 0.8) and unstructured ($B = 12.5$, 95% CI: 10.9, 14.2) physical activity frequency/week (Table 2). Dog play (≥ 3 times/week) was also positively associated with preschooler minutes/day of outdoor play at home ($B = 30.8$, 95% CI: 22.8, 38.9), at the park ($B = 8.2$, 95% CI: 0.5, 15.9) and total outdoor play ($B = 39.1$, 95% CI: 26.2, 52.0). Further, playing with the family dog ≥ 3 times/week was associated with more hours of sleep/day ($B = 0.3$; 95% CI: 0.0, 0.5).

3.4. Adjusted associations between family dog walking ≥ 3 times/week and preschooler movement behaviours (dog owners only)

Family dog walking (≥ 3 times/week) was positively associated with preschooler frequency of structured ($B = 0.5$, 95% CI: 0.2, 0.8) and unstructured ($B = 10.5$, 95% CI: 8.8, 12.3) physical activity per week (Table 1); while preschoolers who walked with their dog ≥ 3 times/week also did significantly more minutes/day of outdoor play at home ($B = 10.3$, 95% CI: 1.9, 18.8), at the park ($B = 21.1$, 95% CI: 13.5, 28.6) and total outdoor play ($B = 31.4$, 95% CI: 18.4, 44.5). Family dog walking (≥ 3 times/week) was associated with fewer minutes/day of screen time ($B = -16.7$, 95% CI: -31.3 , -2.2). Family dog walking and dog play were not associated with accelerometer-derived physical activity.

4. Discussion

A large proportion (43%) of families had a family dog which is comparable to other nationally representative studies involving young children (Christian et al., 2020). Dog-owning preschoolers accumulated more unstructured physical activity but less outdoor play at the park compared with non-dog owners. However, within dog-owning families, regular (≥ 3 times/week) dog play and family dog walking was positively associated with higher levels of parent-reported preschooler outdoor play (home, park and overall) and unstructured and structured physical activity. These findings are in support of studies in older children showing dog ownership is positively associated with physical activity (Christian et al., 2013; Martin et al., 2015; Owen et al., 2010). They also align with a study reporting that school-aged children (10–12 years) who walk their dog, walk more in their neighbourhood, play more in the street and yard and are more independently mobile (Christian et al., 2014). A recent study has highlighted that regular dog play and family dog walking is positively associated with preschooler social-emotional development (Wenden et al., 2021).

Preschoolers who regularly walked or played with their family dog also had lower screen time and slept more. Only one other study to date has examined the relationship between dog ownership and preschooler screen time, and found no association (Gadomski et al., 2017). There appears to be no studies investigating the relationship between preschooler dog ownership and sleep. The relationships observed may be due in part to dog-facilitated physical activity, rather than dog ownership per se, enabling young children to be more physically active, spend less time on screens and sleep more. It is possible the positive relationships observed are related to the dog–human oxytocin loop (Nagasawa et al., 2015). Previous research has shown the existence of a self-perpetuating oxytocin-mediated positive loop in human–dog relationships that is similar to that of human mother–infant relations (Nagasawa et al., 2015), however another study reported no association (Marshall-Pescini et al., 2019). These relationships require further testing to identify the mechanisms through which dog-facilitated physical activity positively supports preschooler movement behaviours.

It is worth noting that only parent-report and not accelerometer derived measures of preschooler movement behaviours were positively associated with dog-facilitated physical activity. While accelerometers provide an objective measure of preschooler physical activity, they are not context specific (e.g., structured vs. unstructured physical activity, playing outdoors at home/park) and thus may not be sufficiently sensitive to capture the contribution dog-facilitated physical activity makes to preschooler movement behaviours. Furthermore, while preschoolers wore the accelerometer in the same week the parent completed the survey, the survey asked about preschoolers' 'typical' movement behaviours (e.g., structured and unstructured physical activity per week thinking about the last month) which may reflect usual behaviour rather than actual behaviour as captured by the accelerometer.

Overall dog ownership alone may be insufficient to facilitate increased preschooler physical activity. However, playing regularly with the family dog and going on regular family dog walks could be an important source of physical activity for preschoolers and should be investigated as a future intervention strategy. Future studies may also consider using machine learning activity classification models with accelerometer data for more accurate measures of children's movement behaviours (Ahmadi et al., 2020). Overall, these findings highlight that the movement behaviour benefits from dog-facilitated physical activity may begin early in childhood.

5. Strengths and limitations of the study

This study was a secondary analysis of data from the PLAYCE study. Dog ownership was not a primary focus of the PLAYCE study, thus factors such as the number, breed, age and health of the dog and, the level of attachment between the dog and child were unmeasured (Coci et al., 2022). Future studies should collect information on such dog-related factors as well as further socio-demographic factors (e.g., family income, single parent status) and information about the physical environment in which family dog walks occur (e.g., access to parks and dog-related features such as dog exercise areas). Our study was also limited by not including an explicit definition of dog play and family dog walking. Finally, the cross-sectional design did not permit causal inferences to be made. However, this study had a number of strengths including the large representative sample of preschoolers from a range of socio-demographic backgrounds, the inclusion of several movement behaviour-related outcomes and the use of both objective and parent-report measures of movement behaviours.

6. Conclusion

Dog-facilitated physical activity provided through playing with the family dog and family dog walking, rather than dog ownership per se, may support healthy movement behaviours (physical activity, minimal screen time, adequate sleep) in young children. This study highlights the unrealised capacity for family dog walking and dog play to improve young children's movement behaviours. Further research to identify casual relationships and the mechanisms through which dog-facilitated physical activity may improve preschooler movement behaviours is required. Given the large proportion of families with young children who have a dog, such interventions may be simple, low-cost and a potentially effective way to increase preschooler movement behaviours.

CRedit authorship contribution statement

Hayley Christian: Conceptualization, Funding acquisition, Methodology, Investigation, Supervision, Writing – original draft, Writing – review & editing. **Elizabeth J. Wenden:** Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Michelle Ng:** Writing – review & editing. **Clover Maitland:** Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors thank the families who participated in the PLAYCE study for their time and commitment.

Funding

This study in part was funded by the Human-Animal Bond Research Institute (HABRI) (Grant no. HAB17-017). The authors acknowledge the support of the Western Australian Health Promotion Foundation (Healthway) who supported the original PLAYCE study (#24219). Hayley Christian is supported by a National Heart Foundation Future Leader Fellowship (#102549). Elizabeth Wenden is supported by an Australian Research Training Program Scholarship.

References

- Carson, V., Lee, E.-Y., Hewitt, L., et al., 2017. Systematic review of the relationships between physical activity and health indicators in the early years (0–4 years). *BMC Public Health* 17 (5), 854.
- Australian Government Department of Health. Australian 24-Hour Movement Guidelines for the Early Years (Birth to 5 years): An integration of physical activity, sedentary behaviour, and sleep. Commonwealth of Australia. <https://www.health.gov.au/internet/main/publishing.nsf/Content/npra-0-5yrs-brochure>. Published 2017. Accessed 25th November 2021.
- Cliff, D.P., McNeill, J., Vella, S.A., Howard, S.J., Santos, R., Batterham, M., Melhuish, E., Okely, A.D., de Rosnay, M., 2017. Adherence to 24-hour movement guidelines for the early years and associations with social-cognitive development among Australian preschool children. *BMC Public Health* 17 (S5). <https://doi.org/10.1186/s12889-017-4858-7>.
- Roman-Viñas, B., Chaput, J.-P., Katzmarzyk, P.T., Fogelholm, M., Lambert, E.V., Maher, C., Maia, J., Olds, T., Onywera, V., Sarmiento, O.L., Standage, M., Tudor-Locke, C., Tremblay, M.S., 2016. Proportion of children meeting recommendations for 24-hour movement guidelines and associations with adiposity in a 12-country study. *Int. J. Behav. Nutr. Phys. Act.* 13 (1) <https://doi.org/10.1186/s12966-016-0449-8>.
- Christian, H.E., Westgarth, C., Bauman, A., Richards, E.A., Rhodes, R.E., Evenson, K.R., Mayer, J.A., Thorpe, R.J., 2013. Dog ownership and physical activity: a review of the evidence. *J. Phys. Act. Health* 10 (5), 750–759.
- Rhodes, R.E., Baranova, M., Christian, H., Westgarth, C., 2020. Increasing physical activity by four legs rather than two: systematic review of dog-facilitated physical activity interventions. *Br. J. Sports Med.* 54 (20), 1202–1207.
- Christian, H., Trapp, G., Lauritsen, C., Wright, K., Giles-Corti, B., 2013. Understanding the relationship between dog ownership and children's physical activity and sedentary behaviour. *Pediatric Obesity* 8 (5), 392–403.
- Martin, K.E., Wood, L., Christian, H., Trapp, G.S.A., 2015. Not just "A walking the dog": dog walking and pet play and their association with recommended physical activity among adolescents. *Am. J. Health Promot.* 29 (6), 353–356.
- Christian, H., Trapp, G., Villanueva, K., Zubrick, S.R., Koekemoer, R., Giles-Corti, B., 2014. Dog walking is associated with more outdoor play and independent mobility for children. *Prev. Med.* 67, 259–263.
- Owen, C.G., Nightingale, C.M., Rudnicka, A.R., Ekelund, U., McMinn, A.M., van Sluijs, E. M.F., Griffin, S.J., Cook, D.G., Whincup, P.H., 2010. Family dog ownership and levels of physical activity in childhood: findings from the Child Heart and Health Study in England. *Am. J. Public Health* 100 (9), 1669–1671.
- Coci, M., Saunders, J., Christian, H., 2022. Barriers and motivators for preschoolers playing and walking with their dog: Results from qualitative research [published online ahead of print, 2021 Mar 22]. *Health Promot. J. Austr.* 33 (1), 19–27.
- Wenden, E.J., Lester, L., Zubrick, S.R., Ng, M., Christian, H.E., 2021. The relationship between dog ownership, dog play, family dog walking, and pre-schooler social-emotional development: findings from the PLAYCE observational study. *Pediatr. Res.* 89 (4), 1013–1019.
- Christian, H., Mitrou, F., Cunneen, R., Zubrick, S.R., 2020. Pets are associated with fewer peer problems and emotional symptoms, and better prosocial behavior: findings from the Longitudinal Study of Australian Children. *J. Pediatr.* 220, 200–206.e2.
- Christian, H., Maitland, C., Enkel, S., Trapp, G., Trost, S.G., Schipperijn, J., Boruff, B., Lester, L., Rosenberg, M., Zubrick, S.R., 2016. Influence of the day care, home and neighbourhood environment on young children's physical activity and health: protocol for the PLAYCE observational study. *BMJ Open* 6 (12), e014058. <https://doi.org/10.1136/bmjopen-2016-014058>.
- Hinkley, T., Salmon, J.o., Okely, A.D., Crawford, D., Hesketh, K., 2012. The HAPPY study: development and reliability of a parent survey to assess correlates of preschool children's physical activity. *J. Sci. Med. Sport* 15 (5), 407–417.

- Burdette, H.L., Whitaker, R.C., Daniels, S.R., 2004. Parental report of outdoor playtime as a measure of physical activity in preschool-aged children. *Arch. Pediatr. Adolescent Med.* 158 (4), 353–357.
- Pate, R.R., O'Neill, J.R., Mitchell, J., 2010. Measurement of physical activity in preschool children. *Med. Sci. Sports Exercise* 42 (3), 508–512.
- Gadomski, A.M., Scribani, M.B., Krupa, N., Jenkins, P., 2017. Pet dogs and child physical activity: the role of child-dog attachment. *Pediatric Obesity* 12 (5), e37–e40.
- Nagasawa, M., Mitsui, S., En, S., Ohtani, N., Ohta, M., Sakuma, Y., Onaka, T., Mogi, K., Kikusui, T., 2015. Social evolution. Oxytocin-gaze positive loop and the coevolution of human-dog bonds. *Science* 348 (6232), 333–336.
- Marshall-Pescini, S., Schaeb, F.S., Gaugg, A., Meinert, A., Deschner, T., Range, F., 2019. The role of oxytocin in the dog-owner relationship. *Animals* 9 (10), 792. <https://doi.org/10.3390/ani9100792>.
- Ahmadi, M.N., Pavey, T.G., Trost, S.G., 2020. Machine learning models for classifying physical activity in free-living preschool children. *Sensors (Basel)* 20 (16), 4364.