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Article

Associations of friendship and children's physical activity during and outside of school: A social network study

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ABSTRACT

Friendships play a significant role in child development and may influence children's physical activity (PA). Using a whole-network approach, this study examined whether school-based friends are more similar in their pedometer-measured PA compared to children who are not friends, and whether these patterns vary by gender, strength of friendship (best vs. close friends), and during vs. outside of school. The analytical sample included 706 grade 5 students (10- to 11-years-old) in 27 schools who were participating in the APPLE Schools project (Alberta Project Promoting healthy Living for Everyone in schools) in Edmonton and Fort McMurray, Alberta, Canada in the spring of 2013. Data collected included student and parent survey responses, time-stamped pedometer data for nine consecutive days, and close and best within-school and within-grade friendship nominations. We used Multiple Regression - Quadratic Assignment Procedure (MR-QAP) to examine the effect of friendship ties on PA similarity overall, and for during and outside of school periods, controlling for covariates and clustering within schools. When all friendships (i.e., close and best) were considered, female friends exhibited more similar levels of overall PA than non-friends, and these findings held for school days, the during-school period, and non-school days. When close and best friends were examined separately in the same model (non-friends as the referent), both close and best friends were more similar than non-friends. The close friendship findings held for non-school days, and the best friendship findings held for school days, including the during-school and before- and after-school periods. For males, only reciprocated best friends had more similar levels of overall PA compared to unreciprocated friendships and non-friends. Programs and policies that focus on increasing PA in children may benefit from incorporating friendship-based strategies and programming, especially for females.

1. Introduction

Participation in regular physical activity (PA) is important for the psychological, motor, and physical development of children (Poitras et al., 2016). Despite these known benefits, only a small proportion of children and adolescents globally are sufficiently active (Hallal et al., 2012; Tremblay et al., 2016). For instance, in Canada only 33% of young people aged 6- to 17-years-old meet the Canadian PA guidelines of 60 min of moderate-to-vigorous physical activity (MVPA) per day when PA is averaged across the week (Colley et al., 2017). Additionally, PA levels steadily decline when children enter formal schooling (Reilly, 2016), making the childhood years an ideal time to intervene. Identifying consistent modifiable correlates and determinants of children's PA is important to inform evidence-based practice (Sallis, Owen, & Fotheringham, 2000).

Children live in peer-rich worlds and spend significant amounts of time with peers and friends at school, on playgrounds, and while participating in organized activities. Thus, by virtue of time spent together, these interactions, provide a context in which development occurs (Bagwell & Schmidt, 2011). Also, children like doing PA with friends rather than alone (Sanders et al., 2014), and describe their friends as influencing their PA in various ways such as modeling, co-participation, and encouragement (Jago et al., 2009). Thus, through social learning processes, such as rewards, punishments and role modeling (Bukowski, Buhrmester, & Underwood, 2011), friends may influence the behaviour of one another.

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Investigating patterns of behaviour among friends, such as similarity of PA, can provide insights into why some children are more active than others, and the potential role of friends in shaping their PA. Social network theory is ideal for studying friendships because it acknowledges the important role of dyadic relationships and social networks in explaining cognition and behaviour (Valente, 2010). Indeed, a main tenant of this theoretical perspective is that people tend to be friends with others who are similar to them on demographic factors, beliefs, and behaviour, and this similarity is due to several factors (Valente, 2015). These include selecting friends who are similar to oneself (*selection*), friends influencing one another over time (*influence*), along with other factors.

Social network analysis involves a distinct set of techniques that allow us to measure and analyze the complex nature of friendship networks (Valente, 2010). Data collected via whole-network research designs can provide rich data on the relationships between actors in a bounded network (e.g., grade-level within a school), as well as actor's personal attributes such as attitudes and behaviour (Borgatti, Everett, & Johnson, 2013). Thus, instead of relying on the participants perceptions of their personal network which can be prone to bias, we can directly measure PA using activity monitors in all children and consequently all of their friends. An examination of the similarity of PA among friends in comparison to non-friends using a dyad-level analysis also considers the PA levels of everyone in the network, and thus takes into account who is available to select as a friend in the network (i.e., opportunity; McPherson, Smith-Lovin, & Cook, 2001). Though limited, existing whole-network research supports the hypothesis that friends across the ages of 8- to 11-years-old have similar levels of accelerometer-measured PA (Gesell, Tesdahl, & Ruchman, 2012; Macdonald-Wallis, Jago, Page, Brockman, & Thompson, 2011; Salway, Sebire, Solomon-Moore, Thompson, & Jago, 2018). However, several questions remain unanswered including whether similarity in PA among friends varies by friendship strength, during vs. outside of school, and gender.

Friendship strength is an important consideration because best friends are thought to have the greatest influence on one another (de la Haye, Robins, Mohr, & Wilson, 2011). This hypothesis, however, has yet to be tested in the childhood years. Variation in the similarity of PA during and outside of school could also be important. Specifically, because children are with their friends at school for a large portion of the school day (>7 hs more opportunities exist to spend time together and to influence one another at school compared to outside of school. Differences in similarity of PA during vs. outside of school could also provide clues as to the processes by which friends influence one another (e.g., co-participation, modeling). To our knowledge, no study has examined similarity of objectively-measured PA of both children and their friends for during and outside of school periods.

A final consideration is whether similarity of PA among friends holds for both males and females. It is widely known that friendship networks in childhood are very gender segregated (Rose & Smith, 2009), and that males are more active than females (Bauman et al., 2012). Friendships are also experienced differently for males and females (Sherman, De Vries, & Lansford, 2000). For example, females often spend time talking and engaging in intimate disclosure with friends (Rose & Smith, 2009), whereas males often do activities with friends such as play sports (Marks, de la Haye, Barnett, & Allender, 2015; Mathur & Berndt, 2006) and tend to hang out in larger peer groups (Rose & Smith, 2009). Thus, gender differences in the similarity of PA among friends is an important research question.

The purpose of this research was to examine whether school-based friends are more similar in their pedometer-measured PA compared to children who are not friends. Further, we investigated whether this similarity in PA varies by gender, strength of friendship (i.e, close vs. best friends), and during vs. outside of school. We hypothesized that close and best friends would be more similar in their PA compared to non-friends, with a stronger magnitude of effect for best friends. We further hypothesized that male friends (best, close) would be more similar in their PA compared to female friends, and that friends (best, close) would be more similar in their PA on school days compared to non-school days.

2. Methods

2.1. Participants and procedures

Employing a cross-sectional design, data were collected from grade 5 children (10- to 11-years-old) participating in the APPLE Schools project (Alberta Project Promoting healthy Living for Everyone in schools; www.appleschools.ca) in Edmonton and Fort McMurray, Alberta, Canada. Schools in Edmonton residing in low socioeconomic status neighborhoods were invited to participate in the program (Fung et al., 2012). Conversely, all schools in Fort McMurray were invited. Every year, all schools involved with the APPLE Schools program are surveyed. In 2013, the survey included questions on friendship but nine of the 42 schools opted not to participate in the friendship portion of the survey, and six additional schools did not have sufficient data ($\geq$ 50% participation rate and pedometer compliance was required). Across the 27 schools, two schools had participation/compliance rates $>$ 90%, four had rates between 80% and 89%, six had rates between 70% and 79%, six had rates between 60–69%, and nine had rates between 50% and 59%.

A consent form and parent survey were sent home with students and completed by a parent. Four trained research assistants then visited the classrooms at each school. Assent from the students was obtained, height and weight were measured behind a screen, a student survey was administered (including friendship questions), and instructions for pedometer wear were provided. These procedures took approximately 60 min of class time. The students were instructed to wear the pedometer for nine consecutive days on their right hip and overtop of their right knee; to take the device off when swimming, showering or when deemed unsafe to wear; and to fill out their log book daily (Vander Ploeg, Wu, McGavock, & Veugelers, 2012). Teachers, the school health facilitator, and researcher assistants reminded students during the week to wear their pedometer and complete their logbook.

Within the 27 included schools, 1049 students were registered, of which 912 were present for data collection and distributed a survey, and 790 ultimately participated (87% participation rate). Parental consent and valid friendship network data were available for 779 participants, and valid pedometer data was available for 715 participants. The final analytical sample consisted of 27 schools and 706 participants (47% males).

The initial APPLE Schools project and this specific research study were approved by the University of Alberta Research Ethics Board (HREB). The school boards and schools also provided consent. The research team made every effort to ensure free and informed consent as well as confidentiality.

2.2. Friendship network

Using an open-ended social network survey format each participant provided the first and last name of up to 10 close friends (i.e., "other children who you hang around with, talk to, and do things with the most") in their school and grade level (de la Haye, Robins, Mohr, & Wilson, 2010). They also indicated which of their close friends were considered best friends (maximum of five).

Friendship was represented as 2-level (non-friends, friends) and 3-level variables (non-friends, close friends, best friends) using N by N square matrices (see Fig. 1b). Because most of the observed friendships were between children of the same gender (females: 91%, males: 87%), separate networks were created for males and females, which is consistent with other studies (de la Haye et al., 2010; Salway et al., 2018). The networks from all schools were combined in one dataset with relationships between students in different schools not considered (i.e.,

a. Attribute or person-level data.

Name	Steps/day	Weight status
Bob	10,352	0
Joe	7,598	1
Sue	11,219	1
Liz	8,239	0

b. Dyad-level data – friendship tie where 0 = non-friend and 1 = friend. It is also directional meaning that if one person nominates a peer as a friend, this peer may not nominate them back.

	Bob	Joe	Sue	Liz
Bob		1	0	0
Joe	1		0	0
Sue	1	0		1
Liz	0	1	1	

c. Dyadic-level data – absolute difference in steps.

	Bob	Joe	Sue	Liz
Bob		2754	867	2113
Joe	2754		3621	641
Sue	867	3621		2980
Liz	2113	641	2980	

d. Dyadic-level data - Same vs. opposite weight status, where 0 = not same and 1 = same.

	Bob	Joe	Sue	Liz
Bob		0	0	1
Joe	0		1	0
Sue	0	1		0
Liz	1	0	0	

Fig. 1. Examples of (a) person-level data, and dyadic-level data for (b) friendship ties, (c) absolute difference in steps, and (d) same weight status.

set as missing). These matrices were also directional, meaning a child could nominate a peer in the network, but the peer may not nominate this child back. For descriptive purposes, students were asked two follow-up questions pertaining to the number of close friends at the school who were not in their grade, and the number of close friends who did not attend their school.

2.3. Physical activity

The Omron HJ-720ITC (Ontario, Canada), a time-stamped piezo-electric pedometer, was used as an objective measure of PA. This device records hourly steps and wear time, and resets every night, thus eliminating the need for participants (or others) to record their steps. This memory function is thought to reduce the potential reactivity effect of visual feedback (Lubans et al., 2015). Evidence for the criterion validity of this model and other Omron models has been demonstrated with children (Hart, Brusseau, Kulinna, McClain, & Tudor-Locke, 2011; Nakae, Oshima, & Ishii, 2008; Peters, Kate, & Abbey, 2013).

As described in Vander Ploeg et al. (2012), step-estimates for non-ambulatory and non-wear activities recorded in the children's diaries were calculated and added to the hourly steps (i.e., referred to here as log-imputed steps). Due to differing administration and collection times at schools and as per recommended practice, the first and last days of pedometer data were not analyzed.

PA was operationalized as steps/hour to account for differing valid hours between participants (Laurson, Welk, & Eisenmann, 2015). Steps/hour was calculated as steps taken during each time period (all days, school days, non-school days [Saturday, Sunday, holidays], during-school, before/after-school) divided by the number of valid hours (worn or log-imputed). Total crude and log-imputed steps/day (6 a.m. to 12 a.m.) were also created for descriptive purposes. For each hourly pedometer outcome an absolute difference matrix was created for each dyad in the network (see Fig. 1a and c).

Days and periods with ~ 60% or more valid hours (worn or log imputed) were included. This was based on other studies that required participants to be wearing the device for ~ 60% or more of their waking hours (Peters et al., 2013; Vander Ploeg et al., 2012). Because steps/hour was the outcome we limited the hours to periods when 70% of the participants were wearing the pedometer (Catellier et al., 2005). The accuracy of the proprietary wear time function was also observed to drop off at 8 p.m., and thus valid hours were only considered before this time. A valid school day included eight or more valid hours between 7 a.m. and 8 p.m., and a valid non-school day included seven or more valid hours between 9 a.m. and 8 p.m. A valid during-school period included five or more valid hours between 8 a.m. and 4 p.m., and a valid before- and after-school period included three or more valid hours between 7 a.m. to 8 a.m. and 4 p.m. to 8 p.m. The during-school period included one hour before and one hour after school to capture travel to and from school (Vander Ploeg et al., 2012).

All days, school days, during school, and before/after-school required two valid days to be included. Non-school days required one valid day. This was based on research that reported two valid days as sufficient to represent a week (Craig, Tudor-Locke, Cragg, & Cameron, 2010). Though other studies require a weekend day because PA tends to decrease on the weekends (Lubans et al., 2015), a paired samples *t*-test showed steps/hour was not significantly different between school days and non-school days in both males ($t[190] = -2.0, p = .84$) and females ($t[276] = 1.12, p = .26$).

Based on recommendations in the literature for addressing cut-offs for outliers (Lubans et al., 2015), full days (6 a.m. to 12 a.m.), school days (7 a.m. to 8 p.m.) and non-school days (9am to 8 pm) with < 1000 steps were deleted, and days with > 30,000 steps were truncated. Similarly, during-school periods with < 500 steps, and before- and after-school periods with < 300 steps were also removed. Days where > 50% of the hours included zero steps were also removed to help ensure days where the pedometer was not worn were excluded.

Students also reported how frequently they participated in before-school, lunch-time, or after-school physical activities organized by their school in the spring (i.e., season the pedometers were worn; response options: never, less than once per week, 1 to 3 times per week, and 4 or more times per week). This variable was transformed into an absolute difference matrix.

2.4. Weight status

Weight was measured using a calibrated scale (nearest 0.1 kg) and height using a stadiometer (nearest 1.0 mm). Categorizations of *non-overweight* ($z < 1$) and *overweight/obese* ($z \geq 1$) were based on the World Health Organization's (WHO) growth reference (de Onis et al., 2007; World Health Organization, 2007). This variable was transformed into a "same as" matrix (see Fig. 1a and d).

2.5. Demographics

A parent indicated their highest level of education (responses: elementary or less, secondary, community/technical college, university, and graduate university), whether they were born in Canada (responses: yes/no), household income (responses: less than $25,000, $25,001–$50,000, $50,001–$75,000, $75,001–$100,000, more than $100,000, don't know/prefer not to answer), and the gender of their child.

2.6. Analysis

Analyses were completed using IBM SPSS 24 (IBM Corporation, 2016), UNICET 6 and NetDraw 2.157 (Borgatti, Everett, & Freeman, 2002). Person-level descriptive statistics were run in SPSS, whole-networks were visually inspected via Netdraw, and dyadic-level regressions were run in UCINET.

Separate models were run for each pedometer step outcome (absolute difference in total steps, school day steps, non-school day steps, during-school steps, before/after-school steps). Separate models were

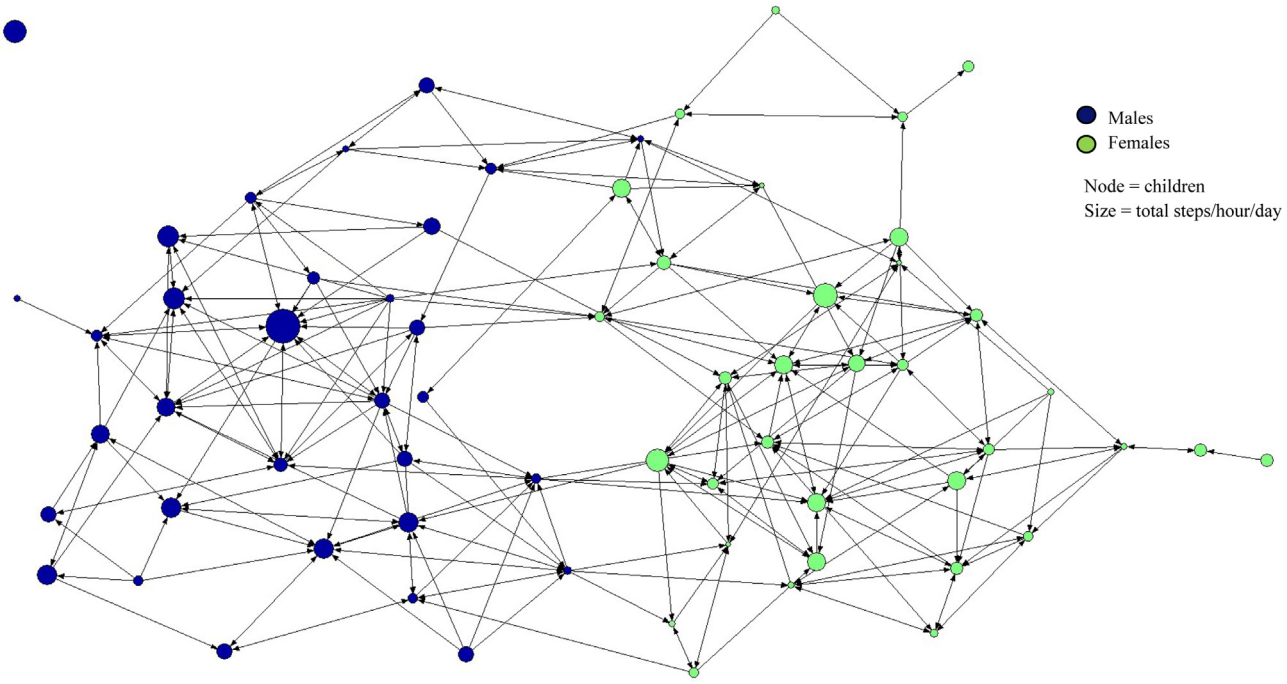

Fig. 2. Example of a friendship network of grade 5 children from one school.

also run for (1) all friendship ties (friends vs. non-friends) and (2) close and best friendship ties (referent non-friends). A significant negative beta coefficient for friendship indicated the difference in PA between friends was smaller than the difference in PA between non-friends (i.e., were more similar). Because of the known association between PA and adiposity in children (Poitras et al., 2016), same weight status was included as a covariate. A significant negative beta coefficient indicated those with the same weight status (i.e., non-overweight vs. overweight/obese) had less of a difference in PA (i.e., were more similar) than those with a different weight status. Absolute difference in school PA was also controlled (except in the non-school day analyses) to account for possible similarity of PA due to participation in the same school organized activities rather than friendship. A significant positive beta coefficient indicated pairs who engaged in a similar frequency of school organized PA also took a similar amount of steps. We controlled for clustering within schools using fixed effects modeling by including 26 dummy school variables in the models (largest school as referent; Huang, 2016).

Because dyad-level data inherently violates the assumption of independence of observations, multiple regression quadratic assignment procedure (MR-QAP) was used to account for network dependencies (e.g., transitivity, reciprocity) without explicitly modeling them (Borgatti et al., 2013). Using this simulation procedure, each dyadic observation is transformed into long columns and the "observed" beta coefficient is calculated using typical linear regression procedures. Thousands of new matrices are then created with the same properties as the original data (e.g., same mean, standard deviation) and autocorrelational properties preserved, yet with the rows randomly rearranged (thus making them independent from the original matrix). The proportion of "simulated" coefficients as large as (for positive expected findings) or as small as (for negative expected findings) the "observed" coefficient is the *p*-value. A one-tailed significance test with 2000 permutations was used, unstandardized beta coefficients (B) are presented, and statistical significance was set at $p < .05$.

Several post hoc analyses were run separately with *total steps* to address potential limitations and to test whether methodological decisions impacted findings. First, post-hoc tests explored whether schools with lower participation/compliance rates (< 70%) had different findings than schools with higher rates (≥ 70%). Social network studies typically require high participation rates (e.g., ≥ 70%) because missing data has large impacts on dyadic-level data. Therefore, it was important to explore whether our inclusion of schools with participation rates of ≥ 50% impacted findings. This was tested by adding school participation/compliance rate (i.e., < 70% vs. ≥ 70%; entered as a sender effect in matrix format) and the interaction between participation/compliance and friendship into the existing model. Second, we tested whether schools with only one grade 5 classroom had different results than schools with more than one grade 5 classroom as proximity (i.e., being in the same classroom) is a strong predictor of friendship (Tsai et al., 2016), and not controlling for class could have attenuated findings. This was tested by adding the number of classes in the school (i.e., 1 class vs. > 1 class; entered as a sender effect in matrix format) and the interaction between number of classes and friendship into the existing models. Finally, because studies in developmental psychology typically use reciprocated friendships only (i.e., both children nominate each other as friends; Bagwell & Schmidt, 2011), we ran the models again only using reciprocated friendships and the results were compared to the main analyses.

Those with parent consent, student assent, friendship data, and recorded steps were included. In some instances where we had parent consent and pedometer data but no friendship data (total $n = 11$), outgoing friendship ties were replaced with incoming friendship ties (Borgatti et al., 2013; Huisman, 2009). Of the included participants, 1.7% were missing on gender, 6.2% on weight status, and 4.2% on school organized PA. To maximize the number of observations included in the main analysis, expectation maximization was used to impute missing data on weight status and school PA. This procedure is superior to traditional approaches such as mean replacement, and may be the best approach when more advanced methods (e.g., multiple imputation) are not possible and missing data is low (Cox, McIntosh, Reason, & Terenzini, 2014; Tabachnick & Fidell, 2007). Because gender homophily is well known phenomenon (McPherson et al., 2001), and was clearly present in the network maps (see Fig. 2), cases missing on

Table 1
Sociodemographic information of grade 5 students participating in the APPLE Schools project in 2013.

Characteristics	Females		Males		Total sample	
	n	Statistic	*n*	Statistic	*n*	Statistic
No. participants per school size – mean (min, max)		14 (3, 47)		12 (3, 34)		35 (17, 93)
Age – mean (SD)	369	10.81 (0.36)	324	10.86 (0.42)	693	10.83 (0.39)
Weight status – count (%)						
Healthy weight	206	59%	148	48%	354	54%
Overweight	145	41%	162	52%	307	46%
Parent born in Canada - count (%)[+]						
No	133	37%	73	23%	206	31%
Yes	224	63%	240	77%	464	69%
Parent education – count (%)[+]						
Secondary school or less	85	24%	89	29%	174	26%
Community/technical college	141	41%	116	37%	257	39%
University	64	18%	65	21%	129	20%
Graduate school	58	17%	40	13%	98	15%
Household income – count (%)						
< $25,000	16	7%	12	6%	28	7%
$25,000-$50,000	30	14%	23	11%	53	12%
$50,001-$75,000	30	14%	20	10%	50	12%
$75,001-$100,000	23	10%	26	13%	49	11%
> $100,000	124	56%	127	61%	251	58%
School-organized PA (frequency/week) – mean (SD)	366	1.69 (1.60)	311	1.73 (1.65)	677	1.71 (1.62)

Note. Numbers may not tally to 706 because of missing data; PA = physical activity; [+]characteristics are of the parent who completed the parent survey (82.1% female).

gender were replaced with the gender of the majority of their friends. We did not impute missing data for any pedometer recordings due to the large percentage of missing data for non-school day steps.

3. Results

The average number of participants per school was 35 (range of 17 to 93), and the number of grade 5 classes per school ranged between 1 and 5 (see Table 1). The rate of overweight/obesity (46%) was higher than the Canadian average (33%; Roberts, Shields, de Groh, Aziz, & Gilbert, 2012). The median household income was > $100,000/year, with 69% making $75,000 or more per year, which is similar to rates in Alberta (i.e., median of $100,130 in 2015; Statistics Canada, 2017a). Slightly higher proportions of responding parents were born outside of Canada (31%) and had attained a bachelor's degree (35%) compared to the Canadian population (immigrants in Canada: 21.9%; Statistics Canada, 2017b; attained a bachelor's degree: 31% of women and 26% of men in 2016; Statistics Canada, 2016).

Across the 27 schools 4,357 close friendship nominations were given, of which 3,559 (82%) were to participating students and 113 (3%) were to identifiable non-participating students (i.e., we had records of the child). Additionally, 685 (16%) nominations were to unmatched individuals (e.g., no records of the child, recently moved, friends outside of the network). Of the nominated close friends, 2403 were considered best friends, of which 57 (2%) were to identifiable non-participating students, and 421 (12%) were to unmatched individuals. The mean number of outgoing friendship ties for females was 3.89 and for males was 3.45 (Table 2). The mean number of outgoing best friendship ties for females was 2.27 and for males was 2.12. Further, children reported 3.70 close school friends in a different grade and 5.64 close friends from outside of -school. Number of close school friends in a different grade or school did not differ by gender, weight status, or inactivity status (i.e., < 12,000 steps/day). Thus, across different groups, children had similar numbers of friends that were not captured in our school- and grade-level networks.

Children had an average of 5.07 valid days, 12.22 valid hours on school days (i.e., between 7 a.m. and 8 p.m.), and 9.94 valid hours on non-school days (i.e., between 9 a.m. and 8 p.m.; see Table 3). Average steps/hour were 798 across the week, 804 for school days, 807 for non-school days, 826 for during-school, and 807 for before- and after-school. PA was significantly higher in males for every outcome.

An inspection of the friendship network maps by school with individual nodes sized by their PA level indicated potential clustering of PA among friends (see Fig. 2). The main analysis tested whether friends were more similar on their PA compared to children that were not friends, controlling for covariates (see Table 4). Compared to the difference in PA between female non-friends, the difference in PA between female friends was approximately **20** steps/hour lower for the whole week (B = -20.04, p = .001), **19** steps/hour lower for school days (B = -19.32, p = .001), **9** steps/hour lower during-school (B = -9.20, p = .027), and **34** steps/hour lower for non-school days (B = -33.62, p = .030). For males, the difference in steps/hour between friends was not statistically different from the difference in steps/hour between non-friends for any outcome.

Post hoc analyses did not show a statistically significant interaction between participation/compliance rates (< or ≥ 70%) and friendship ties for total steps in females (B = -1.25, p = .454) or males (B = -21.16, p = .105). Also, no interaction existed between number of grade 5 classes (1 class vs. > 1 class) and friendship ties for total steps in females (B = 2.44, p = .451) and males (B = -1.00, p = .488). The findings from Table 4 also held when separate analyses were run for only reciprocated friendships for females (B = -20.03, p = .005) and males (B = -5.53, p = .318). Therefore, the findings would not have changed if we chose to use stricter participation/compliance rates, only included schools with one grade 5 class, or only included reciprocated friendships.

Table 5 presents the findings of whether close and best friends were more similar on their PA than non-friends, controlling for covariates. Compared to the difference in PA between female non-friends, the difference in PA between female close friends was **20** steps/hour lower for the whole week (B = -19.55, p = .014) and was **51** steps/hour lower for non-school days (B = -51.32, p = .020). Also compared to the difference in PA between female non-friends, the difference in PA between female best friends was **21** steps/hour lower for the entire week (B = -20.99, p = .005), **24** steps/hour lower for school days (B = -24.32, p = .001), **11** steps/hour lower for during-school (B = -11.52, p = .020), and **26** steps/hour lower for before- and after-school (B = -26.33, p = .031). For males, the difference in steps/hour between close and best friends was not significantly different from the difference in steps/hour between non-friends for any outcome.

Table 2
Social network information of grade 5 students participating in the APPLE Schools project in 2013.

Characteristics	Females	Males	Total sample	Female vs. male comparison
Close friendship network				
In-degree – mean (SD)	3.89 (2.21)	3.45 (2.18)	3.68 (2.21)	$t(704) = 2.71^{*}$
Out-degree – mean (SD)	3.89 (2.33)	3.45 (2.37)	3.68 (2.36)	$t(704) = 2.53^{**}$
Reciprocated dyads - %	50%	46%		
Best friendship network				
In-degree – mean (SD)	2.27 (1.53)	2.12 (1.57)	2.20 (1.55)	$t(704) = .1.31$
Out-degree - mean (SD)	2.27 (1.59)	2.12 (1.74)	2.20 (1.66)	$t(704) = 1.22$
Reciprocated dyads - %	46%	40%		
Friendships outside of grade or school				
Close school friends in a different grade – mean (SD)	3.49 (3.26)	3.95 (3.38)	3.70 (3.32)	$t(685) = -1.83$
Close non-school friends – mean (SD)	5.65 (3.56)	5.64 (3.65)	5.64 (3.60)	$t(685) = .05$

Note. In-degree = number of incoming friendship nominations per student; out-degree = number of outgoing friendship nominations per student; reciprocated dyads = unreciprocated ties/reciprocated ties; in-degree, out-degree, and friendships outside of grade or school were compared between males and females using independent samples *t*-tests; $^{*}p < .05$, $^{**}p < .01$.

Post hoc analyses did not show a significant interaction between participation/compliance (< or ≥ 70%) and close and best friendship for total steps in females (close: B = -4.34, $p = .405$; best: B = 2.63, $p = .447$) and males (close: B = -7.10, $p = .390$; best: B = -32.25, $p = .077$). There was also no interaction between number of grade 5 classes (1 class vs. > 1 class) and close and best friendship for females (close: B = 11.15, $p = .298$; best: B = -4.42, $p = .409$) and males (close: B = -41.18, $p = .071$; best: B = 18.49, $p = .238$). When the analysis for total steps was run for reciprocated friendships only, close and best friendships were significant in females (close: B = -24.71, $p = .010$; best: B = -16.136, $p = .040$), and best friendships were significant in males (close: B = 27.09, $p = .960$; best: B = -17.60, $p = .048$). Therefore, the findings would not have changed if we chose to use stricter participation/compliance rates, or only included schools with one grade 5 class. However, including only reciprocated friendships did impact the results for males.

4. Discussion

This study assessed whether school-friends are more similar in their pedometer-measured PA compared to children who are not friends, and variation by gender, strength of friendship, and during vs. outside of school PA. We took a unique whole-network dyad-level approach to measure close and best school-friendship ties and pedometer-measured PA in grade 5 children (10- to 11-years-old). Instead of relying solely on the children's general perceptions of their friend's PA, which could be prone to bias, we objectively measured PA in all participants, and consequently all of their school-friends. Though some studies have used social network methodology to measure friendship and PA in children (i.e., 5–11 years-old) and their friends (Jago et al., 2011; Marks et al., 2015), few have used an approach that takes into account the behaviour of everyone in the network (i.e., friends and non-friends; Gesell et al., 2012; Macdonald-Wallis et al., 2011; Salway et al., 2018), and thus who is available to select as a friend in the network (i.e., opportunity; McPherson et al., 2001). It is also an intuitive way to analyze friendship data because friends inherently exert bidirectional influences on one another. We observed female friends to be similar in their overall PA, with close friends being similar on non-school days and best friends being similar on school days. Specifically, the difference in PA between close female friends was 20 steps/hour lower than the difference in PA between females who were not friends, which amounts to a difference of 160–260 steps/day. For males, overall PA was only similar for reciprocated best friends. Though the effects are small, we believe our findings support the value of friendship-based PA strategies within multi-component programs or interventions in late childhood.

Our findings are generally consistent with other studies that employed a whole-network dyadic-level approach to friendships and PA in children. Using auto-regressive procedures, clustering of accelerometer-measured MVPA and total PA have been observed with 10- to 11-year-old children (Macdonald-Wallis et al., 2011) and 8- to 9-year-old females and males in the UK (Salway et al., 2018). Gender differences between Salway et al. (2018; stronger effects in males) and our study (effects mainly in females) could be due to the statistical analysis employed, or the type of activity assessed (accelerometer MVPA vs. pedometer steps). Using stochastic-actor based modeling, children in two after-school care programs adjusted their accelerometer-measured

Table 3
Pedometer steps of grade 5 students who were participating in the APPLE Schools project in 2013.

	Females		Males		Total sample	
	n	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)
Hourly steps						
Total steps/hour	376	744 (236)	329	861 (313)	705	798 (281)**
School day steps/hour	370	752 (221)	323	864 (286)	693	804 (259)**
Non-school day steps/hour	283	730 (466)	198	918 (608)	481	807 (537)**
During-school steps/hour	369	765 (211)	320	896 (275)	689	826 (252)**
Before and after-school steps/hour	354	758 (402)	292	866 (506)	646	807 (455)**
Daily steps						
Crude total steps/day	376	7716 (2402)	329	8664 (2946)	705	8159 (2709)**
Log-imputed steps/day	376	9635 (3119)	329	10809 (3941)	705	10183 (3573)**
Valid days and hours/day						
Valid days	376	5.35 (1.63)	330	4.75 (1.63)	706	5.07 (1.66)**
School day valid hours[1]	376	12.33 (.80)	329	12.09 (.91)	705	12.22 (.86)*
Non-school day valid hours[1]	283	9.91 (1.10)	198	9.98 (1.01)	481	9.94 (1.07)

Note. [1]Valid hours include wear time and log-imputed hours, school day valid hours were between 7 a.m. and 8 p.m., and non-school day valid hours were between 9 a.m. and 8 p.m.; $^{*}p < .05$; $^{**}p < .01$.

Table 4
Association between friendship ties and difference in pedometer-measured physical activity (steps/hour) for grade 5 students participating in the APPLE Schools project in 2013.

	All days	School days	During-school	Before- and after-school	Non-school days
Females					
n of observations	7462	7320	7272	6778	4618
Model 1					
Non-friends	Ref	Ref	Ref	Ref	Ref
Friendship	**-19.79 (.002)**	**-19.01 (.001)**	**-9.14 (.028)**	-17.46 (.068)	**-33.59 (.034)**
Model 2					
Non-friends	Ref	Ref	Ref	Ref	Ref
Friendship	**-20.04 (.001)**	**-19.32 (.001)**	**-9.20 (.027)**	-17.52 (.078)	**-33.62 (.03)**
Same weight status	12.83 (.998)	13.33 (.999)	12.35 (1.00)	10.53 (.883)	1.43 (.55)
Difference in school PA	0.78 (.349)	-0.29 (.457)	**3.78 (.012)**	3.65 (.180)	n/a
Males					
n of observations	5416	5314	5214	4516	2072
Model 1					
Non-friends	Ref	Ref	Ref	Ref	Ref
Friendship	-5.04 (.290)	-0.06 (.501)	3.51 (.679)	-13.83 (.226)	1.01 (.513)
Model 2					
Non-friends	Ref	Ref	Ref	Ref	Ref
Friendship	-2.60 (.338)	2.55 (.602)	6.86 (.818)	-13.04 (.231)	0.40 (.50)
Same weight status	4.00 (.705)	3.28 (.702)	**-14.02 (.009)**	-12.15 (.193)	14.83 (.72)
Difference in school PA	**13.36 (.001)**	**14.11 (.001)**	**14.41 (.001)**	2.37 (.332)	n/a

Note. Unstandardized beta coefficients are presented with proportion significant (i.e., *p*-value) in parentheses; **bold** text indicates significance at $p < .05$; a significant negative beta coefficient for friendship indicates that friends are more similar in their PA than non-friends; a significant negative beta coefficient for weight status indicates that pairs with the same weight status are more similar in their PA than pairs with a different weight status; a significant positive beta coefficient for difference in school PA indicates that pairs who engage in a similar frequency of school organized PA also take a similar amount of steps; fixed effects modeling was used to control for clustering within schools.

MVPA over four months by 10% or more to be consistent with their friend's PA, yet they did not select friends based on activity level (5–12 years-old; Gesell et al., 2012). Though Gesell et al. (2012) was focused on PA in after-school care and did not separate analyses by gender, the study does provide evidence that friends in childhood do in fact influence one another over time. This is consistent with research in adolescents, whereby best friend influence had a stronger effect than selection for self-reported PA (de la Haye et al., 2011). Taken together, these studies support the importance of friends in shaping PA in childhood and adolescence. It is therefore reasonable to assume that a large proportion of the similarity effect between friends observed in our study may be due to influence as well.

Table 5
Association between close and best friendship ties and difference in pedometer-measured physical activity (steps/hour) for grade 5 students participating in the APPLE Schools project in 2013.

	All days	School days	During-school	Before- and after-school	Non-school days
Females					
n of observations	7462	7320	7272	6778	4618
Model 1					
Non-friend	Ref	Ref	Ref	Ref	Ref
Close friend	**-19.51 (.017)**	-12.75 (.056)	-6.19 (.174)	-4.30 (.406)	**-51.28 (.014)**
Best friend	**-20.62 (.006)**	**-23.85 (.001)**	**-11.47 (.025)**	**-26.37 (.030)**	-22.27 (.147)
Model 2					
Non-friend	Ref	Ref	Ref	Ref	Ref
Close friend	**-19.55 (.014)**	-12.83 (.057)	-6.21 (.167)	-4.47 (.338)	**-51.32 (.02)**
Best friend	**-20.99 (.005)**	**-24.32 (.001)**	**-11.52 (.020)**	**-26.33 (.031)**	-22.29 (.16)
Same weight status	12.83 (.997)	13.38 (.999)	12.37 (1.00)	10.56 (.888)	1.49 (.54)
Difference in school PA	0.77 (.351)	-0.33 (.458)	**3.76 (.017)**	3.60 (.189)	n/a
Males					
n of observations	5416	5314	5214	4516	2072
Model 1					
Non-friend	Ref	Ref	Ref	Ref	Ref
Close friend	13.10 (.835)	13.50 (.850)	9.10 (.798)	13.04 (.697)	12.98 (.628)
Best friend	-16.11 (.078)	-8.14 (.235)	0.17 (.516)	-30.15 (.087)	-6.77 (.443)
Model 2					
Non-friend	Ref	Ref	Ref	Ref	Ref
Close friend	15.63 (.885)	16.12 (.901)	12.16 (.864)	13.62 (.687)	12.07 (.61)
Best friend	-13.74 (.110)	-5.54 (.311)	3.68 (.657)	-29.22 (.096)	-7.18 (.43)
Same weight status	4.10 (.730)	3.37 (.683)	**-13.96 (.008)**	-11.92 (.195)	14.69 (.73)
Difference in school PA	**13.37 (.001)**	**14.11 (.001)**	**14.41 (.001)**	2.36 (.669)	n/a

Note. Unstandardized beta coefficients are presented with proportion significant (i.e., *p*-value) in parentheses; **bold** text indicates significance at $p < .05$; a significant negative beta coefficient for close or best friends indicates that close or best friends are more similar in their PA than non-friends; a significant negative beta coefficient for weight status indicates that pairs with the same weight status are more similar in their PA than pairs with a different weight status; a significant positive beta coefficient for difference in school PA indicates that pairs who engage in a similar frequency of school organized PA also take a similar amount of steps; fixed effects modeling was used to control for clustering within schools.

We hypothesized that a stronger magnitude of effect would be observed for best friends compared to close friends. This distinction is important because higher quality friendships (i.e., best friendships) are thought to have a greater influence than lower quality friendships (de la Haye et al., 2011). For all PA done across the week, evidence for this hypothesis was only found for males (specifically for reciprocated best friends). However, for females, differences between close and best friends were observed for different days and time periods. Specifically, close female friends were similar on their PA for non-school days, with the difference in PA between close friends being 51 steps/hour lower than the difference in PA between non-friends, which amounts to a difference of 408 to 663 steps/day. Best friends were similar on their PA for school days and periods (during and before/after school), with a 12 to 26 step/hour lower difference in PA between best friends compared to non-friends, which amounts to a difference of 96 to 338 steps/day. It is possible that children's best friends are typically from school (as they have a wider pool of friends to choose from), whereas close friends are from their neighborhood or organized activities (yet also attend the same school). Consequently, if most of their time at school is spent with their best friends, then their best friends may have the greatest influence during school days. On the other hand, they may have more opportunities to spend time with close friends on non-school days (e.g., playing in the neighborhood or during organized activities), and thus close friends have the greatest influence on non-school days. The practical implications of these findings are that friendship-based interventions, aimed at increasing the PA of females throughout the week, can focus on their wider group of friends. Yet, within schools a particular focus on best friends for both males and females would be beneficial.

The general lack of significant findings for males, and larger effect sizes observed for females compared to males, was unexpected considering PA is a salient aspect in the lives of males in childhood (Jago et al., 2009), males often play sports with their friends (Marks et al., 2015; Mathur & Berndt, 2006), and a recent systematic review concluded that friends have a larger influence on the PA of males than females (Sawka, McCormack, Nettel-Aguirre, Hawe, & Doyle-Baker, 2013). For males, we only found similarity of PA for male best reciprocated friendships. Specifically, the difference in PA between male best reciprocated friends as 18 steps/hour lower than the difference in PA between unreciprocated friendships or non-friends, which amounts to a difference of 144–234 steps/day. The null effects for close friendships may be explained by the tendency for males to hang out in larger groups (Rose & Smith, 2009). If a large proportion of the males at a school play sports during recess and lunch time, then we may not observe differences in PA between close friends and non-friends particularly for school periods. Further, best friends likely spend additional time together outside of the peer group, which could explain the similarity observed for best male reciprocated friends. It is also possible that male close friends are similar on higher intensity PA only. This is consistent with a study of adolescents that observed similarity in organized but not unorganized PA for both males and females (de la Haye et al., 2010), and a study of children that observed similarity of MVPA among male and female friends (Salway et al., 2018).

Because our study is cross-sectional, the observed similarity of PA between friends could be due to children selecting friends who are similarly active (*selection*) or friends influencing one another over time (*influence*; Valente, 2015), however both are likely involved and work in a feedback loop (de la Haye & Salvy, 2016). Further, friendship influence on PA could be due to several factors such as modeling, co-participation, peer group norms, and encouragement from active friends (Bandura, 1989; Salvy, de la Haye, Bowker, & Hermans, 2012; Sawka et al., 2013). We suspect that all of these processes play a role (Berkman, Glass, Brissette, & Seeman, 2000). Future research should examine several processes simultaneously as well as potential mechanisms (e.g., enjoyment, self-efficacy) to either support or refute the role of different theories.

Our findings support the value of friendship-based PA programming or strategies in late childhood. Public health decision makers, health promotion professionals, schools, and parents should be made aware of the potential influence of friends on PA in this age-group, particularly for females, and to harness this influence to promote healthy behaviour. For example, to help facilitate healthy "influence" among friends, PA programs can incorporate relationship skill building activities to help children develop physical skills as well as healthy, high quality relationships. Further, considering low activity tends to cluster within friendship groups, it may be worthwhile to target low active groups specifically (de la Haye et al., 2010). For example, schools could talk to inactive friendship groups about what types of activities they would like to do together and offer these activities for them.

Our study has several strengths. First, we had a relatively large sample size of schools and children from underserved communities, who are typically hard to reach. Second, the whole-network methodology allowed us to capture both incoming and outgoing friendships and to complete whole-network dyad-level analyses. Third, the time-stamped piezo-electric pedometers permitted us to objectively measure ambulatory PA, examine during and outside of school PA, and complete log-imputations for non-ambulatory and non-wear periods to better capture children's actual patterns of PA. Further, the memory function of the device helped reduce potential reactivity (Lubans et al., 2015).

Several limitations should, however, be mentioned. First, a large proportion of children (particularly males) did not have valid data for non-school days, and thus the results for non-school day PA could be biased. Despite the increased accuracy of activity monitors, poor compliance is a well-known yet difficult to overcome limitation of these devices (Lubans et al., 2015). Second, because this is a cross-sectional design we cannot be certain that friends influenced the PA of one another, and similarity in PA between friends is likely due to the combination of selection and influence. Third, the participants were involved in the APPLE Schools project, a comprehensive school health program that has demonstrated effectiveness of improving PA levels (Fung et al., 2012; Vander Ploeg, McGavock, Maximova, Veugelers, 2014), and thus the findings may not generalize to schools without health promotion initiatives. Fourth, other unaccounted for processes (e.g., similarity on ethnicity, being in the same class, family factors), may explain the observed findings.

A final consideration is that our findings only generalize to school-based same-gender friendships. Because of the whole-network design, and the ease of collecting data within schools, we were only able to collect data on friends from school. Indeed, the children did indicate having many other friends outside of their school and grade level. However, research in this age-group suggests children have strong friendships with peers from school and spend a great deal of time with these friends (Jago et al., 2009). Future research should explore outside of school friendship networks, and cross-gender friendships.

In summary, female close and best school-friends, and male reciprocated best school-friends exhibit similarity in their pedometer-measured PA. This similarity is likely due to both selection and influence processes and the influence effects could be due to modeling, peer group norms, co-participation, and encouragement from active friends. Friendship-based PA programming may be an effective strategy for increasing PA in late childhood.

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