The Role of Friendship Networks in the Physical Activity and Screen Time of Children

by

Jodie Anne Stearns

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Faculty of Kinesiology, Sport, and Recreation
University of Alberta

ABSTRACT

Children's friendships and the wider friendship networks for which these relationships are embedded, are significant contexts for children's development, and may play a role in shaping children's physical activity (PA) and screen time (ST) levels. The purpose of this dissertation was to examine the role of friendship networks in the PA and ST of grade 5 children (10-11 years-old). Participants were involved in the APPLE Schools project (A Project Promoting healthy Living for Everyone in schools) in Edmonton and Fort McMurray, Canada, in 2013. They wore piezo-electric time-stamped pedometers for 9 consecutive days and completed a sociometric survey of their close and best within-school and within-grade friendships. Parents reported on demographic characteristics and children reported their ST, friend support for PA and ST, along with barrier self-efficacy and enjoyment for PA. **Study 1** 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 across gender, strength of friendship (best versus close friends), and during vs. outside of school. Best female friends exhibited similar levels of PA on school days and close female friends on non-school days. Only male best reciprocated friends were similar on their total PA levels. **Study 2** investigated whether characteristics of the friendship network are associated with the pedometer-measured PA and self-reported ST of children, and differences by gender. For females, friend PA was positively associated with their PA, and friend screen co-participation and friend ST (paired with daily friend discouragement of sedentary activities) were positively associated with their ST. In-isolate females (i.e., those with none or only one incoming friendship) had lower levels of ST than those with two or more incoming friendships. Whereas for males, friend PA, friend support for PA, and in-degree centrality (i.e., social status) were positively associated with their PA, and friend

discouragement of sedentary activities and co-participation in screen activities were associated with their ST. Both in- and out-isolate males (i.e., those with none or only one incoming or outgoing friendship) were less active than non-isolates. **Study 3** examined whether enjoyment and barrier self-efficacy for PA mediated associations between characteristics of the friendship network and the pedometer-measured PA of children, and differences by gender. In males, enjoyment of PA mediated positive associations between friend support for PA and child PA, and in-degree centrality and child PA. Though friend support for PA was positively associated with enjoyment and self-efficacy for PA in females, no mediation effects were observed. The findings from this dissertation may inform the development of friendship network strategies for health promotion programming within families, schools, the community, and/or media campaigns.

PREFACE

This dissertation uses data collected through the 2013 APPLE Schools evaluation, which was led by Dr. Paul Veugelers and Dr. Kate Storey in the School of Public Health at the University of Alberta. I was responsible for conceptualizing the studies and contributed to survey development by identifying/developing the friendship questions to be added to the existing survey. I also assisted the APPLE Schools team with data collection and was responsible for the social network data entry, data analysis, and writing of the manuscripts. Finally, I calculated the hourly pedometer data for this project, including data cleaning (wear time, steps) and creating the summary variables. Dr. Biao Wu completed the imputation of steps based on non-wear and non-ambulatory activities reported in the student logbooks.

DEDICATION

This dissertation is dedicated to my husband Craig Stearns and my 3-year old son Blake Stearns. They are my motivation every day.

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GLOSSARY OF TERMS

Actor: Individuals in a network. Also called a node.

Adolescents: Individuals aged 12-17 years-old.

Alter: A nominated person in a social network survey.

Children: Individuals aged 5-11 years-old.

Density: The number of observed ties in a network divided by the total number of possible ties.

Ego: The respondent in a social network survey.

Friends/Friendships: Reciprocated and voluntary relationships among peers who consider one another equals, and that typically involves a shared history, spending time together, and mutual affection.

Function of networks: The interpersonal processes that explain how social networks influence behaviour.

In-degree centrality: Number of incoming friendship nominations.

In-isolate status: Individuals who received no or few incoming friendship nominations.

Node: Individuals in a network. Also called an actor.

Organized PA/sport: PA or sport participation where a coach or instructor is present.

Out-degree centrality: Number of outgoing friendship nominations.

Out-isolate status: Individuals who gave no or few outgoing friendship nominations.

Peers: Other individuals who are around the same.

Social norms: The social pressure one feels to perform or not perform a particular behaviour. It includes both descriptive norms (i.e., perceptions of how others typically behave in specific contexts) and injunctive norms (i.e., perceptions of others approval or disproval of a behaviour)

Physical activity: Physical movements involving energy expenditure.

Physically active: A label for those who meet physical activity guidelines (e.g., ≥ 60 min of MVPA/day in young people).

Physically inactive: A label for those who do not meet physical activity guidelines (e.g., < 60 min of MVPA/day in young people).

Reciprocity: Whether two actors both nominate one another as friends (i.e., reciprocated friendship) or whether one actor nominates another, yet the nomination is not received back (i.e., unreciprocated friendship).

Screen time: Time spent using screen-based devices such as a TV, computer, video game console, or phone.

Sedentary behaviour: A sitting or reclined position and low energy expenditure.

Selection: A process whereby individuals choose friends that have similar characteristics, attitudes and behaviour.

Sitting-related behaviour: Activities often done while sitting.

Social network analysis: A set of techniques used to measure and analyze interactions and relationships among people and their influence on behaviour.

Social networks: The constellation of relationships among individuals.

Social support: A function of social relationships where aid and assistance is exchanged through interpersonal interactions.

Structure: The organization and characteristics of social networks (e.g., density, number of ties).

Unorganized PA/sport: PA or sport participation where a coach is not present.

ACRONYMS

APPLE Schools = Alberta Project Promoting healthy Living for Everyone in schools

CSAQ = Child Sedentary Activity Questionnaire

ERGM = exponential random graph modeling

ICC = intraclass correlation coefficient

METs = metabolic equivalents

MVPA = moderate-to-vigorous physical activity

PA = physical activity

PACES = Physical Activity Enjoyment Scale

QAP = Quadratic Assignment Procedure

SB = sedentary behaviour

SCT = social cognitive theory

SNA = social network analysis

SNT = social network theory

ST = screen time

CHAPTER 1: Introduction

Movement and play are natural components of children's lives. Thus, for healthy growth and development, children (i.e., aged 5-11 years) should participate in regular *physical activity* (PA; Tremblay, Carson, et al., 2016) and avoid long periods of being sedentary. PA is defined as physical movement involving energy expenditure (> 1.5 Metabolic Equivalents [METs]; Caspersen, Powell, & Christenson, 1985; Tremblay et al., 2017), which, in children, includes activities such as active play, active transportation, and organized sports. *Sedentary behaviour* (SB) is not merely an absence of PA but rather involves pursuits done at low energy expenditure (i.e., ≤ 1.5 METs) in a sitting, reclined, or lying posture while awake (Sedentary Behaviour Research Network, 2012). *Screen time* (ST), the consumption of which is often deemed a type of SB, is of particular concern as it has the strongest associations with negative health outcomes in children and adolescents (Carson et al., 2016). Because ST is typically assessed with no information on posture or energy expenditure, it is considered as a *sitting-related behaviour* in this dissertation.

Guidelines recommend children and adolescents limit their recreational ST to less than two hours/day, and engage in at least 60 minutes of moderate-to-vigorous physical activity (MVPA)/day (Department of Health, 2011; Government of Australia, 2014; Tremblay, Carson, et al., 2016; US Department of Health and Human Services, 2008). However, many children around the world are not meeting these guidelines (Tremblay, Barnes, et al., 2016). Among Canadian children (aged 5-11 years), 60% of males and 35% of females are meeting the PA guidelines as measured by accelerometers, and 70% males and 71% of females are meeting the ST guidelines (Roberts et al., 2017). For Canadian adolescents (aged 12-17 years-old), these proportions drop to 34% of males and 14% of females meeting PA guidelines, and 24% of males

and 33% of females meeting ST guidelines. Further, it is clear that PA declines and sitting-related behaviour increases across childhood and adolescence (Reilly, 2016; Tanaka, Reilly, & Huang, 2014) and that both PA and sitting-related behaviour track from childhood to adulthood (Biddle, Pearson, Ross, & Braithwaite, 2010; Craigie, Lake, Kelly, Adamson, & Mathers, 2011). As such, evidence-based interventions, programs, and policies are needed. Though existing PA and sitting-related interventions have had positive results overall, the effects are small (Biddle, Petrolini, & Pearson, 2014; Metcalf, Henley, & Wilkin, 2012). Therefore, it is pertinent that researchers better understand the correlates and determinants of PA and ST in children so that more effective interventions can be designed and implemented (Sallis, Owen, & Fotheringham, 2000).

Importance of Friendships

Friendships, defined as reciprocated and voluntary relationships among peers who consider one another equals, and that typically involves a shared history, spending time together, and mutual affection (Rubin & Bowker, 2018), are developmentally significant aspects of children's lives (Bagwell & Schmidt, 2011). Children spend a great deal of time with their friends at school and in their neighborhood and, thus, by virtue these interactions provide a context in which development occurs (Bagwell & Schmidt, 2011). Friendships are also unique because, unlike relationships with parents or siblings, which are typically stable influences in young people's lives, children are able to choose who they want to be friends with (Smith & McDonough, 2008). Though some aspects of friendships remain stable across childhood and adolescence such as enjoyable interactions and companionship, the developmental significance of friends changes over time (Bagwell & Schmidt, 2011). In his interpersonal theory, Sullivan (1953), a seminal thinker on peer relationships, described how social needs and tensions change

throughout childhood and adolescence, and how they are satisfied through certain social contexts. Beginning around 9-12 years of age, children develop a need for intimacy and consensual validation of self-worth. This need is satisfied through the development of a close friendship or friendships that involve sensitivity to the others needs along with self-disclosure and collaboration. Children who are unable to form close friendships experience loneliness (Sullivan, 1953). Thus, during this period of development, close friends are particularly important in children's lives and may also be key socialization agents for the development of healthy PA and ST behavioural patterns.

Guiding Theory

Individuals are embedded in thick webs of social connections called *social networks* that tend to influence and constrain behaviour in a multitude of ways (Valente, 2010). *Social network theory* (SNT) moves beyond the focus on individual explanations of behaviour (e.g., attitudes, beliefs) and acknowledges the important role of dyadic relationships and social networks in explaining cognition and behaviour (Valente, 2010). *Social network analysis* (SNA), on the other hand, is a distinct set of techniques which allow us to measure and analyze the complex nature of social networks. SNT has three core tenants including a) people are shaped by and take action in response to their network environment, b) a person's position in their network impacts their behaviour, and, c) the network structure influences the performance of the system (Valente, 2015).

The first tenant of SNT describes how the immediate social network environment can influence behaviour and choices, and how individuals take action in response to their network environment. Friends tend to be similar to one another on demographic characteristics, behaviour and attitudes, a phenomenon that can be explained by at least two network processes (Valente,

2015). *Selection* is a process whereby an individual changes their network to be consistent with their behaviour. For example, a young athlete decides to make friends with peers who also like to play sports. *Influence* is a process whereby an individual changes their behaviour to be consistent with their network. For example, a child increases their video game use because they know their friends all play video games daily and they want to fit in. The influence process is of particular interest to researchers because it provides information on whether interventions, such as targeting friends' behaviours, will be effective at changing an individual's behaviour. Several variables such as tie strength may moderate influence effects. For example, individuals tend to be influenced to a greater extent by their close friends than acquaintances.

The second tenant of SNT describes how key positions in networks, such as being central, a liaison between different groups, and on the periphery, can impact behaviour (Valente, 2015). Those who are central in the network tend to have greater access to information and new ideas; however, they are also more compliant with the norms and values of the community. Those in the periphery tend to be less constrained by social norms than those who are more central, and may be isolated (i.e., receives few or no friendship nominations; *isolate*) which puts them at risk for poor health outcomes. These patterns of behaviour observed across people in different network positions can also be due to selection and influence processes. For example, a child may be selected as a friend often by their peers because they are athletic and seen as "cool" (selection), or children who have many friends may have more opportunities to be physically active with friends and thus are highly active (influence).

Social networks are conceptualized in regards to their *structure,* or the organization and characteristics of social networks (e.g., density, number of ties), and their *function*, or the interpersonal processes and mechanisms that explain how social networks influence behaviour

(Langford, Bowsher, Maloney, & Lillis, 1997). Though SNT provides hypotheses around how networks tend to operate, it lacks specificity on the processes and mechanisms (i.e., function) of how networks influence behaviour. To understand these processes and mechanisms I drew upon a multilevel conceptual model (see Figure 1.1) whereby socio-structural conditions, social networks, behavioural mechanisms, and psychobiological processes work in a cascading causal process to influence health (Berkman, Glass, Brissette, & Seeman, 2000; Berkman & Krishna, 2014). The particular components of interest include social networks (e.g., presence of ties, closeness of ties) as providing opportunities for psychosocial mechanisms (e.g., social support, modeling) to occur, which then impact health through behaviour, psychological, and physiological pathways. Using this model as a framework and drawing on several health behaviour theories, I created a working model of friendship networks and the PA and ST of children (see Figure 1.2), which includes the wider social-ecological context, social networks, interpersonal processes, and psychological mechanisms (Stearns & Spence, 2017). I propose the key interpersonal processes by which friends influence the PA and ST of children are modeling, support provision, opportunities/barriers, and negative interactions through psychological factors such as enjoyment of PA, self-efficacy for PA, and social norms around PA. Relevant psychological mechanisms were informed by the *youth physical activity promotion* (YPAP) model which include "Am I able" and "Is it Worth it" constructs (Welk, 1999). Further, consistent with *social cognitive theory* (SCT; (Bandura, 1989, 2004), the working model recognizes triadic reciprocal determinism between behaviour, person (i.e., cognitions, affect, biology), and the environment.

Friendship Networks, Physical Activity, and Screen Time

In the following, I briefly review the literature on friendship networks and the PA and ST of children in *late childhood* (~10-11 years-old), including social support, friend behaviour, network position, and ego-network composition. When limited research is available for this age-group, I draw upon literature with adolescents (i.e., 5-17 years-old) as well.

Friend support for physical activity. Traditionally, the influence of friends on children's PA has been measured as perceptions of social support for PA from friends (e.g., co-participation in PA, encouragement for PA). This variable is consistently and positively associated with PA in late childhood in gender combined samples (Bergh et al., 2011; Ievers-Landis et al., 2003; Kitzman-Ulrich, Wilson, Van Horn, & Lawman, 2010; Silva, Lott, Wickrama, Mota, & Welk, 2012). Further, co-participation in PA with friends and encouragement provided by friends appear to be key components of friend support (Jago et al., 2011; Pearce, Page, Griffin, & Cooper, 2014; Sharma, Hoelscher, Kelder, Day, & Hergenroeder, 2008; Springer, Kelder, & Hoelscher, 2006; Voorhees et al., 2005). Though gender differences have been observed, there is no clear pattern across studies (Jago et al., 2011; Jago, Page, & Cooper, 2012). In addition, there is some evidence that participating on the same sports team can be explained by both selection and influence effects in adolescents. Specifically, those who were enrolled in the same sports tended to become friends over time (selection effects), and over time friends tended to enroll in the same sports (influence effects; i.e., friends influenced their sport participation), yet the influence effects (52%) were much larger than the selection effects (12%; (Fujimoto, Snijders, & Valente, in press). No studies to my knowledge have tested psychological mediators in late childhood, however, qualitative research has shown that children maintain their PA participation over time for the enjoyment of spending time with friends (Jago et al., 2009).

Further, in adolescents, both enjoyment and self-efficacy for PA have been found to mediate the association between friend support for PA and child PA (Chen & Dai, 2016; Chen, Sun, & Dai, 2017; Silva et al., 2012). Thus, general social support from friends is a consistent and positive correlate of PA in late childhood, with co-participation and encouragement being key components.

Friend physical activity. As mentioned previously, a well-known proposition of SNT is that friends tend to be similar to one another on demographic characteristics, behavior, and attitudes (Valente, 2015). In the late childhood years, evidence exists for an association between the PA of a child's friends and their own PA in gender combined samples (Loucaides, Chedzoy, Bennett, & Walshe, 2004; Macdonald-Wallis, Jago, Page, Brockman, & Thompson, 2011) and in both males and females (Marks, de la Haye, Barnett, & Allender, 2015, 2018; Salway, Sebire, Solomon-Moore, Thompson, & Jago, 2018), however there is some variation among friendship variables (e.g., active friends, sports friends) and PA outcomes (e.g., active transportation, school break PA) within studies (Marks et al., 2015, 2018). Further, in one study, the PA of the best friend was positively associated with the PA of the child for males only (Jago et al., 2011) and another did not observe an association with grade 6 females (Voorhees et al., 2005). Studies of the co-evaluation of friendship and PA over time with younger (5-12 years-old) and adolescents find consistent evidence that friends influence one over time (influence) and there is mixed evidence as to whether children and adolescents select friends who are similarly active (selection; de la Haye, Robins, Mohr, & Wilson, 2011; Gesell, Tesdahl, & Ruchman, 2012; Long, Barrett, & Lockhart, 2017; Shoham et al., 2012; Simpkins, Schaefer, Price, & Vest, 2013). No research to my knowledge has examined psychological mediators of the association between friend and child PA, and there have been no identified mediators in adolescents (de la Haye et

al., 2011). Thus, friend PA is associated with PA in late childhood and there is some variation by gender, friendship variables, and PA outcomes.

Network position and physical activity. According to SNT, behaviour within networks can differ by network position, such as being central in the network (i.e., number of incoming friendships; *in-degree centrality*), or an isolate (i.e., received no or few friendship nominations; *isolate status*). Those who are central in the network tend to have greater access to information and new ideas, and thus are often in a position of power or leadership, whereas those who are isolated have less social capitol which puts them at a disadvantage (Valente, 2015). Differences between those who are central and isolated could also reflect opportunities and barriers to be active, as children tend to be more active when in the presence of friend(s) compared to when alone (Sanders et al., 2014). Centrality can be measured via number of incoming (*in-degree centrality*; social status or being well liked; Cillessen & Marks, 2011) or outgoing friendships (*out-degree centrality*; expansiveness or gregariousness; de la Haye et al., 2011). Marks et al. (2015) observed out-degree centrality to be associated with PA in males only, however over time, out-degree was not associated with PA in males or females (Marks et al., 2018). To the contrary, Jago et al. (2012) observed out-degree centrality to be associated with PA both cross-sectionally and longitudinally in females only. Yet, Gesell et al. (2012) did not find actor or partner effects (i.e., equivilant to in- and out-degree centrality) for PA in children (ages 5-12). Further, in a qualitative study of friendship networks, children reported PA ability to be a marker of social status and leadership in male groups, but only in some female groups (Jago et al., 2009). Only one study of adolescents (aged 11-15 years-old) has examined isolates, and observed none these children met the PA guidelines (Sawka et al., 2014). However, studies on the presence of friends also shows that children and adolescents are more physically active when

in the presence of a friend or friends and they are more motivated to be physically active and prefer (e.g., suggesting enjoyment) playing with friends more than playing alone (Barkley et al., 2014; Salvy et al., 2008; Salvy et al., 2009; Sanders et al., 2014). These studies are important as they suggest that PA is more enjoyable when with friends and thus it is possible that isolates may be less active because they simply have less opportunity to play with friends. To the contrary, those with many friends many have numerous opportunities to play with friends, and thus are more physically active. Thus, further research is required on network positions and PA and ST in late childhood, and currently little conclusions can be drawn.

Gender composition and physical activity. Two studies of the same sample of 11- to 13-years-olds examined the gender composition of children's friendship networks and their PA. Males who only nominated male friends had higher levels of PA than males who nominated at least one female friend (Marks et al., 2015). Further, males with an increase in the proportion of same-gender friends over time, also increased their PA over time (Marks et al., 2018). Therefore, males who are friends mostly with males appear to be more active.

Friendship influences and screen time. Less research exists on friendship networks and children's ST, including no research on aspects of social support, such as co-participation (unhealthy influence) or discouragement of screen use or sedentary activities (healthy influence). Perceived friends TV viewing has been associated with children's TV viewing (Te Velde et al., 2014), and with females (11-12 years-old), initial levels of friends ST was associated with her ST, and change in ST over three years was associated with change in her ST (Raudsepp & Riso, 2017). Further, there is some evidence of friendship influence on ST in adolescence but no evidence of selection (Shoham et al., 2012). In regards to network position, out-degree centrality is associated with ST in females both cross-sectionallly and longitudinally (Marks et al., 2015,

2018). Further, in a study of adolescents (11-15 years-old), isolate status was not associated with ST (Sawka et al., 2014). Thus, there is some evidence that friends ST and out-degree centrality are associated with children's ST in late childhood, yet the research is sparse.

Gaps in the Literature and Link to Dissertation

My dissertation addresses several current gaps in the literature on friendship networks, PA, and ST *in late childhood*. First, I examine children in grade 5 (10-11 years-old), which is a developmental period when friends are thought to increase in importance (Sullivan, 1953), yet is an understudied age in the friendship network, PA and SB literature. Second, though consistent evidence exists for similarity of PA among friends and perceived social support for PA from friends in independent studies, few studies (Jago et al., 2009) have combined social network variables and perceived social support for PA to examine their relative importance. Additionally, few studies have examined friendship influences on children's ST. Third, no studies have compared similarity of PA on different days of the week or periods of the day, which could suggest when friends may be the most influential. Fourth, though some work has examined the interpersonal processes by which friendship networks may influence children's PA (e.g., modeling, social support, co-participation; Salvy, De La Haye, Bowker, & Hermans, 2012; Sawka, McCormack, Nettel-Aguirre, Hawe, & Doyle-Baker, 2013), the range of psychological mechanisms by which such influence occurs (e.g., self-efficacy, enjoyment, competence, social norms) has received less attention. Fifth, little research has examined patterns of PA and ST among children central and isolated in the network (i.e., tenant 2 of SNT). As described previously, I have also proposed a working model of friendship networks and children's PA and ST that ties together theories and models specific to this topic area.

Purpose and Data Sources

The **general purpose** of my dissertation was to examine the role of friendship networks in the PA and ST of grade 5 children (10-11 years-old). The three studies use data from a large cross-sectional dataset of in 33 schools in Edmonton and Fort McMurray, Canada, involved with the APPLE Schools project (i.e., A Project Promoting healthy Living for Everyone in schools). **Study 1** examined whether school-based friends are more similar on their pedometer-measured PA compared to children who are not friends, and whether these patterns vary across gender, and strength of friendship (i.e., close friend vs. best friend), and during vs. outside of school. **Study 2** investigated whether characteristics of the friendship network are associated with the pedometer-measured PA and self-reported ST of children, and differences by gender. **Study 3** tested whether enjoyment and barrier self-efficacy for PA mediate associations between aspects of the friendship network and children's pedometer-measured PA and differences by gender.

Significance of the Research

These studies provide insights into the ways in which friendship networks are associated and may influence the PA and ST of children, along with possible psychological mechanisms by which this influence may occur. This knowledge is important for the development and refinement of theory within this area and can be used to inform friendship network interventions within families, schools, the community, and/or media campaigns.

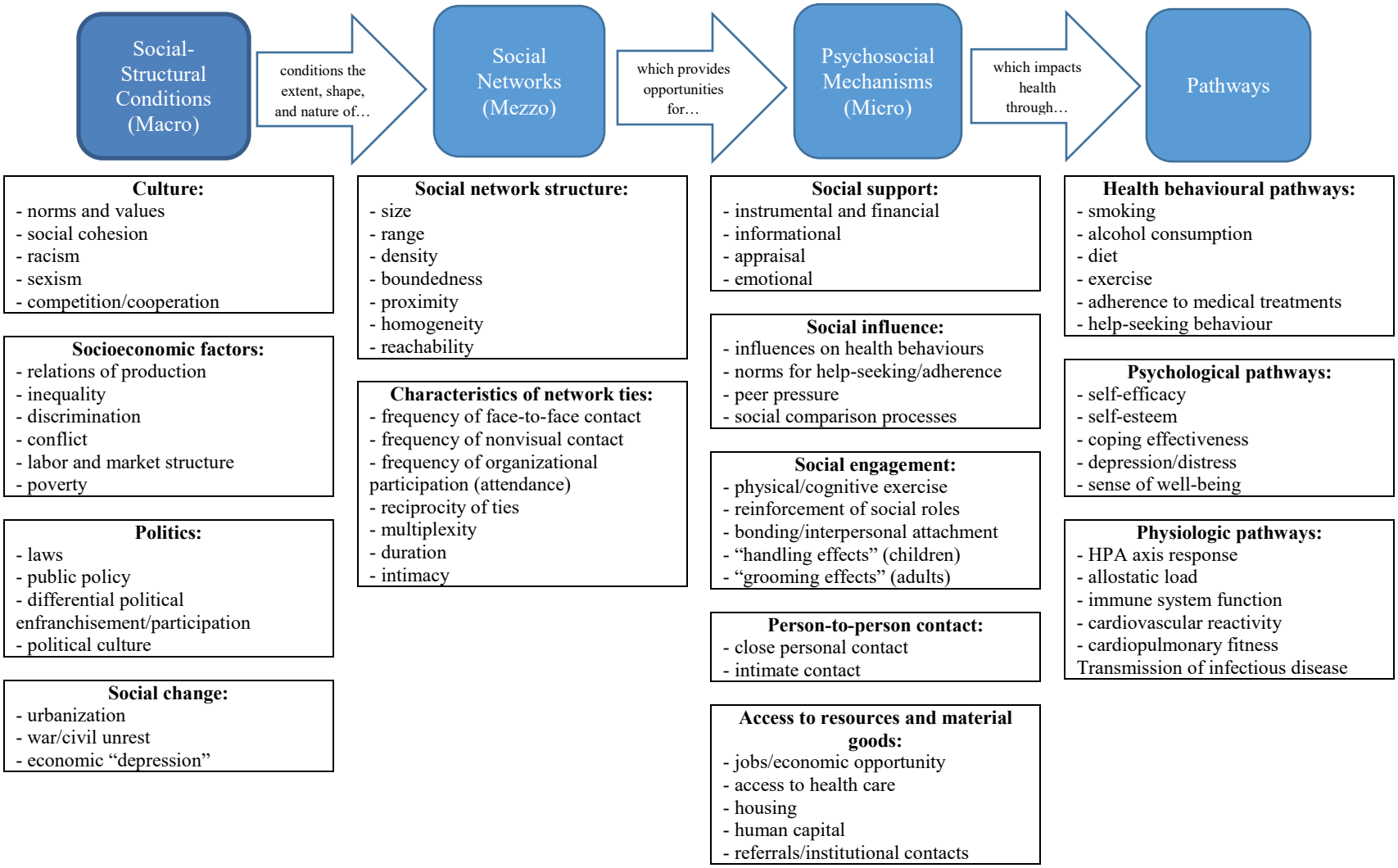

Figure 1.1. Conceptual model of how social networks influence health.

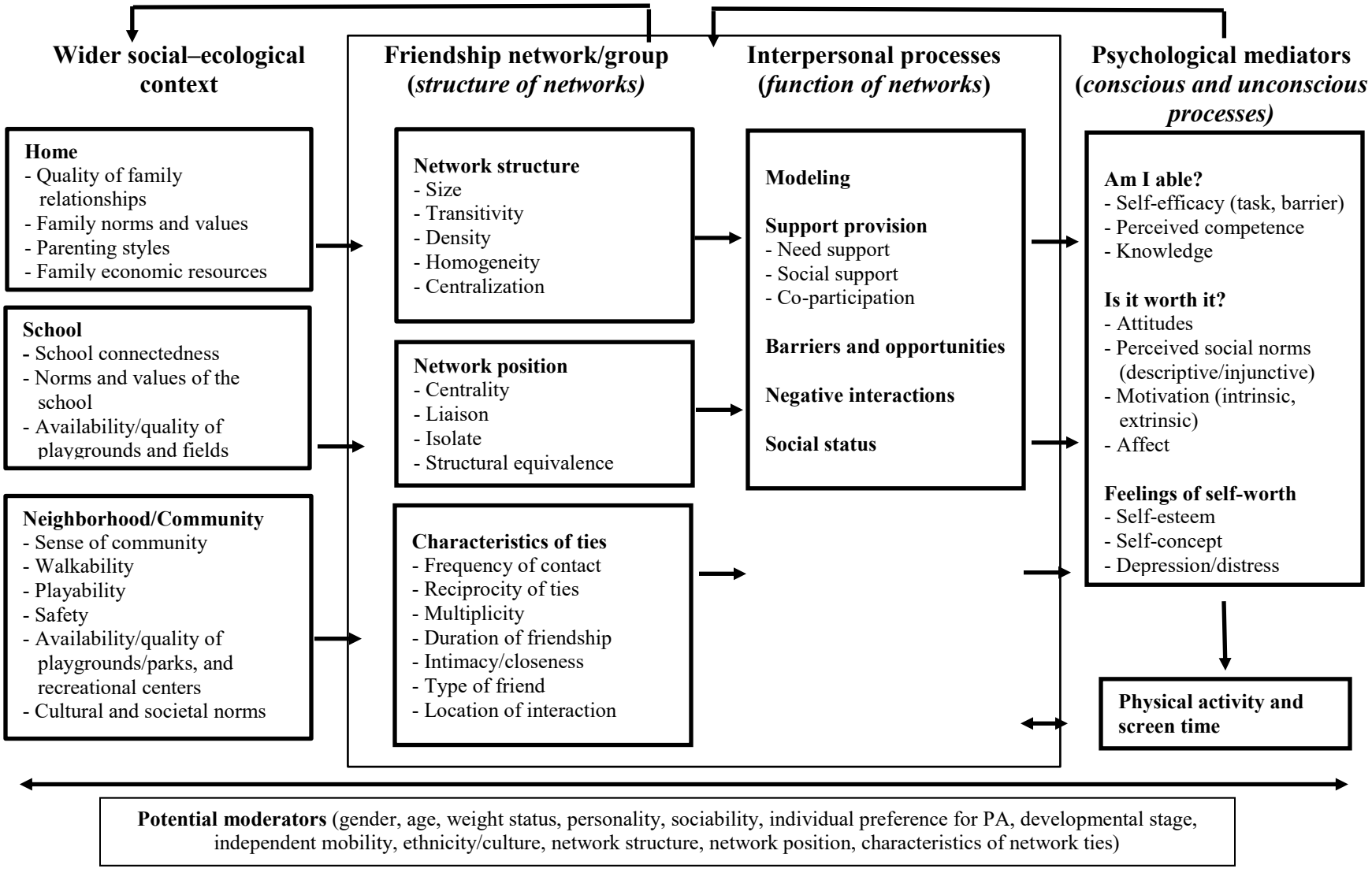

Figure 1.2. Working model of friendship networks and children's physical activity and screen time.

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CHAPTER 2: Study 1

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

Jodie A. Stearns, Paul J. Veugelers, Jenny Godley, John Paul Ekwaru, Kerry Bastian, Biao Wu, & John C. Spence

Abstract

Friendships play a significant role in childhood development and may influence children's physical activity (PA) levels. 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 across gender, strength of friendship (best vs. close friends), and during vs. outside of school PA. The analytical sample included 706 grade 5 students in 27 schools who were participating in the APPLE Schools project (A Project Promoting healthy Living for Everyone in schools) in Edmonton and Fort McMurray, Canada in the spring of 2013. Data collected included student and parent survey responses, time-stamped pedometer data for 9 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 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 PA compared to all other pairs of males in the network. Programs and policies that focus on increasing PA in children may benefit from incorporating friendship-based strategies and programming, especially for females.

Participation in regular physical activity (PA) is important for the social, psychological 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 60% of males and 35% of females aged 5- to 11-years-old meet the Canadian PA guidelines of 60 minutes of moderate-to-vigorous physical activity (MVPA) per day when PA is averaged across the week (Roberts 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).

According to theorizing by Sullivan (1953), around 9-12 years of age, friends increase in importance in children's lives. This shift is due to a developed need for validation and intimacy from peers, along with increased understanding and acceptance of others (Sullivan, 1953). Friendships become closer at this time and offer a context for self-validation, exploration and learning, and a new culture of interests and expectations (Bukowski, 2001). As such, friendships may play an important role in shaping the PA of children.

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

the selection of similar friends (*selection*), friends influencing one another over time (*influence*), and other factors.

Social network analysis provides a set of methodological tools that capture the complexity 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 each school day (>7 hours), 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 in childhood friendship networks are 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 are 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 across gender, strength of friendship (i.e, close vs. best friends), and during vs. outside of school PA. 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.

Methods

Participants and Procedures

This is a cross-sectional study of grade 5 children (10-11 years-old) participating in the APPLE Schools project (A Project Promoting healthy Living for Everyone in schools; www.appleschools.ca) in Edmonton and Fort McMurray, 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, APPLE Schools are surveyed. In 2013, the survey included questions on friendship but 9 of the 42 schools opted not to participate in the friendship portion of the survey, and 6 additional schools did not have sufficient data (<50% participation rate and pedometer compliance). Across the 27 schools, two had >90% participation/compliance rates, four had between 80-89%, six had 70-79%, six had 60-69%, and nine had 50-59%.

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 minutes of class time. The students were instructed to wear a pedometer for 9 consecutive days on the right hip and overtop of the 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 there were 1,049 students registered of which 912 were distributed a survey and 790 students who 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. Also, the research team made every effort to ensure free and informed consent as well as confidentiality.

Measures

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 5).

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 Figure 2.1b). 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., 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.

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 may reduce the potential reactivity effect of visual feedback (Lubans et al., 2015). Evidence of 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). For example, a large correlation was observed between pedometer steps/day with this model and accelerometer-measured MVPA (r = .76) and total PA (r = .79; Peters et al., 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 (6am to 12am) were also created for descriptive purposes. For each hourly pedometer outcome an absolute difference matrix was created for each dyad in the network (see Figure 2.1a and 2.1c).

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 8pm, and thus valid hours were only considered before this time. A valid *school day* included 8 or more valid hours between 7am and 8pm, *non-school day* included 7 or more valid hours between 9am and 8pm, *during-school* period included 5 or more valid hours between 8am and 4pm, and *before- and after-school* period included 3 or more valid hours between 7am to 8am and 4pm to 8pm. The during-school period included 1 hour before and 1 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 2 valid days to be included. Non-school days required 1 valid day. This was based on research that reported 2 valid days to be 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 ($t[276] = 1.12$, $p = .26$).

Consistent with recommendations from the literature (Lubans et al., 2015), full days (6am to 12am), school days (7am to 8pm) and non-school days (9am to 8pm) with <1,000 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 0 steps were also removed to help ensure days where the pedometer was not worn were excluded.

Also, students 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.

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 Figure 2.1a and 2.1d).

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), and 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). Students reported their own gender.

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 step outcome (absolute difference in total steps, school day steps, non-school day steps, during-school steps, before/after-school steps). Separate models were also run for 1) all friendship ties (friends vs. non-friends) and 2) close and best friends (referent non-friends). A significant negative beta coefficient for friendship indicated friends were more similar in their PA than non-friends (i.e., less of a difference). 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 a similar weight status had more similar PA (i.e., less of a difference). Absolute difference in school PA was also controlled (except in 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 by including 26 dummy school variables in the models (largest school as referent; Sawka et al., 2014).

Because dyad-level data inherently violates the assumption of independence of observations, the 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 2,000 permutations was used, unstandardized beta coefficients (B) are presented, and statistical significance was set at $p < .05$.

Several post hoc analyses were run 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. 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. Interaction terms between participation/compliance and friendship, and number of classes and friendship were added to the existing models one at a time for these two post hoc tests. 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 analysis.

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 Figure 2.2), cases missing on 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.

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 2.1). Across the sample, 46% of the children were overweight or obese, which is 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 comparable to rates in Alberta (i.e., median of $100,130 in 2015; Statistics Canada, 2017a). The proportion of responding parents who were born in a country outside of Canada (31%) was higher than the Canadian (21.9%) population (Statistics Canada, 2017b). The proportion of responding parents who had attained a bachelor's degree (35%) was slightly higher than Canadian rates (i.e., 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, 2,403 were considered best friends, of which 57 (2%) were to non-participating students, and 421 (12%) were unmatched.

The mean number of outgoing friendship ties for females was 3.89 (SD = 2.33; 50% reciprocated) and for males was 3.45 (SD = 2.37; 46% reciprocated; see Table 2.2). The mean

number of outgoing best friendship ties for females was 2.27 (SD = 1.59; 46% reciprocated) and for males was 2.12 (SD = 1.74; 40% reciprocated). Further, children reported 3.70 (SD = 3.32) close school friends in a different grade and 5.64 (SD = 3.60) close non-school friends. Number of close school friends in a different grade or school did not differ by gender, weight status, or inactivity (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 (SD = 1.66) valid days, 12.22 (SD = .86) valid hours on school days (i.e., between 7am and 8pm), and 9.94 (SD = 1.07) valid hours on non-school days (i.e., between 9am and 8pm; see Table 2.3). Average steps/hour were 798 (SD = 281) across the week, 804 (SD = 259) for school days, 807 (SD = 537) for non-school days, 826 (SD = 252) for during-school, and 807 (SD = 455) 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 Figure 2.2).

The main analysis which tested whether friends were more similar on their PA compared to children that were not friends, controlling for covariates, is presented in Table 2.4. 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, $p < .01$), **19** steps/hour lower for school days (B = -19.32, $p < .01$), **9** steps/hour lower during-school (B = -9.20, $p < .05$), and **34** steps/hour lower for non-school days (B = -33.62, $p < .05$). 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, *ns*) or males (B = -21.16, *ns*). 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, *ns*) and males (B = -1.00, *ns*). The findings from Table 2.4 also held when separate analyses were run for only reciprocated friendships for females (B = -20.03, $p < .01$) and males (B = -5.53, *ns*). 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 2.5 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, $p < .05$) and was **51** steps/hour lower for non-school days (B = -51.32, $p < .05$). 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, $p < .01$), **24** steps/hour lower for school days (B = -24.32, $p < .01$), **11** steps/hour lower for during-school (B = -11.52, $p < .05$), and **26** steps/hour lower for before- and after-school (B = -26.33, $p < .05$). 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.

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, *ns*; best: B = 2.63, ns) and males (close: B = -7.10, ns; best: B = -32.25, *ns*). 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, *ns*; best: B = -4.42, *ns*) and males (close: B = -41.18, *ns*; best: B = 18.49, *ns*). However, when the analysis for total steps was run for reciprocated friendships only, close and best friendships were non-significant in females (close: B = -8.64, *ns*; best: B = -14.12, $p = .06$), and best friendships were significant in males (close: B = 50.95, *ns*; best: B = -25.81, $p = .02$). 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.

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. Instead of relying solely on the children's general perceptions of their friends 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 studies 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). By considering the behaviour of both friends and non-friends dyad-level analyses help account for potential confounding processes such as opportunity (i.e., who children nominate as friends is partially determined by who is available to select as a friend) and shared environments (e.g., environments can influence entire schools or classrooms). 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 more similar on non-school days and best friends being more similar on school days. For males, overall PA was only similar for reciprocated best friends.

Our findings are generally consistent with the three previous 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 MVPA over four months by 10% or more to be consistent with their friends PA, yet they did not select friends based on activity level (5-12 years-old; Gesell et al., 2012). Although Gesell et al. (2012) was focused on PA in after-school care and did not separate analyses by gender, they do provide evidence that friends in childhood do in fact influence one another over time. This is consistent with research with 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 the childhood years.

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, differences between close and best female friends were observed for different days and time periods. Specifically, close friends were similar on their PA for non-school days and best friends were similar on their PA for school days and periods (during, before/after). It is possible that children's best friends are typically school friends (as they have a wider pool of friends to choose from), whereas close friends are neighborhood friends or friends from organized activities (who also attend the same school). Because females tend to hang out in dyads, it is possible that most time spent at school is with their best friends and thus best friends have the greatest influence during school days. On the other hand, they may be more open to spending 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, can focus on children's wider group of friends. Yet, within schools a particular focus on best friends could provide an added benefit.

The general lack of significant findings for males was unexpected considering PA is a salient aspect in the lives of males in childhood (Jago et al., 2009) and males often play sports with their friends (Marks et al., 2015; Mathur & Berndt, 2006). The null effects may be explained by the tendency for males to hang out in larger groups (Rose & Smith, 2009). If males play unorganized sports during recess and lunch time with a large percentage of the students in their school, then we would not observe differences in PA between friends and non-friends for school periods. It is also possible that male friends are similar on organized activities specifically, as a study of adolescents observed similarity in organized but not unorganized PA (de la Haye et al., 2010).

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). Social influence of friends on PA could be due to several factors including modeling (Bandura, 1989), and social support from active friends, such as co-participation and encouragement (Maturo & Cunningham, 2013). We suspect that all of these processes play a role in why female close and best friends and male reciprocated best friends tend to be similar on their PA (Berkman, Glass, Brissette, & Seeman, 2000). Future research should examine several interpersonal 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 in late childhood. Public health decision makers, health promotion professionals, schools, and parents should be made aware of the powerful influence of friends in this age-group, particularly for females, and to harness this influence to promote healthy behaviour. For example, PA programs can encourage children to bring a friend or come meet a friend, and incorporate relationship skill building activities within a cooperative and friendly environment. They can also 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, directly measure PA from each child using activity monitors, and 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 APPLE Schools, 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, there are other confounding processes that were unaccounted for, such as similarity on ethnicity and being in the same class, which could possibly 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 shows children have strong friendships with their school friends and spend a great deal of time with these friends (Jago et al., 2009). Future research would benefit from exploring outside of school friendship networks, and cross-gender friendships.

In summary, female close and best school-friends, and male reciprocated best friends exhibit similarity in their pedometer-measured PA. This similarity is likely due to both selection and influence effects and influence could be due to interpersonal processes such as modeling, encouragement from active friends, and co-participation. Friendship-based PA programming may be an effective strategy for increasing PA in grade 5 children.

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Table 2.1

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 – 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%
Frequency of school-organized PA – 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).

Table 2.2

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; Same gender ties = same gender ties/all ties; Reciprocated dyads = unreciprocated ties/reciprocated ties; in-degree, out-degree, and friendships outside of grade or school were compared between males and females using an independent samples t-test; *$p < .05$, **$p < .01$

Table 2.3

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 7am and 8pm, and non-school day valid hours were between 9am and 8pm; *$p < .05$; **$p < .01$.

Table 2.4

Association between friendship ties and difference in pedometer-measured physical activity 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 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 those with a similar weight status have more similarity in PA; 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; clustering within schools was controlled for using dummy codes for individual schools.

Table 2.5

Association between close and best friendship ties and difference in pedometer-measured physical activity 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 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 those with a similar weight status have more similarity in PA; 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; clustering within schools was controlled for using dummy codes for individual school.

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		3611	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	

Figure 2.1. Example of person-level (a) and dyadic-level data including friendship ties (b), absolute difference in steps (c), and same weight status (d).

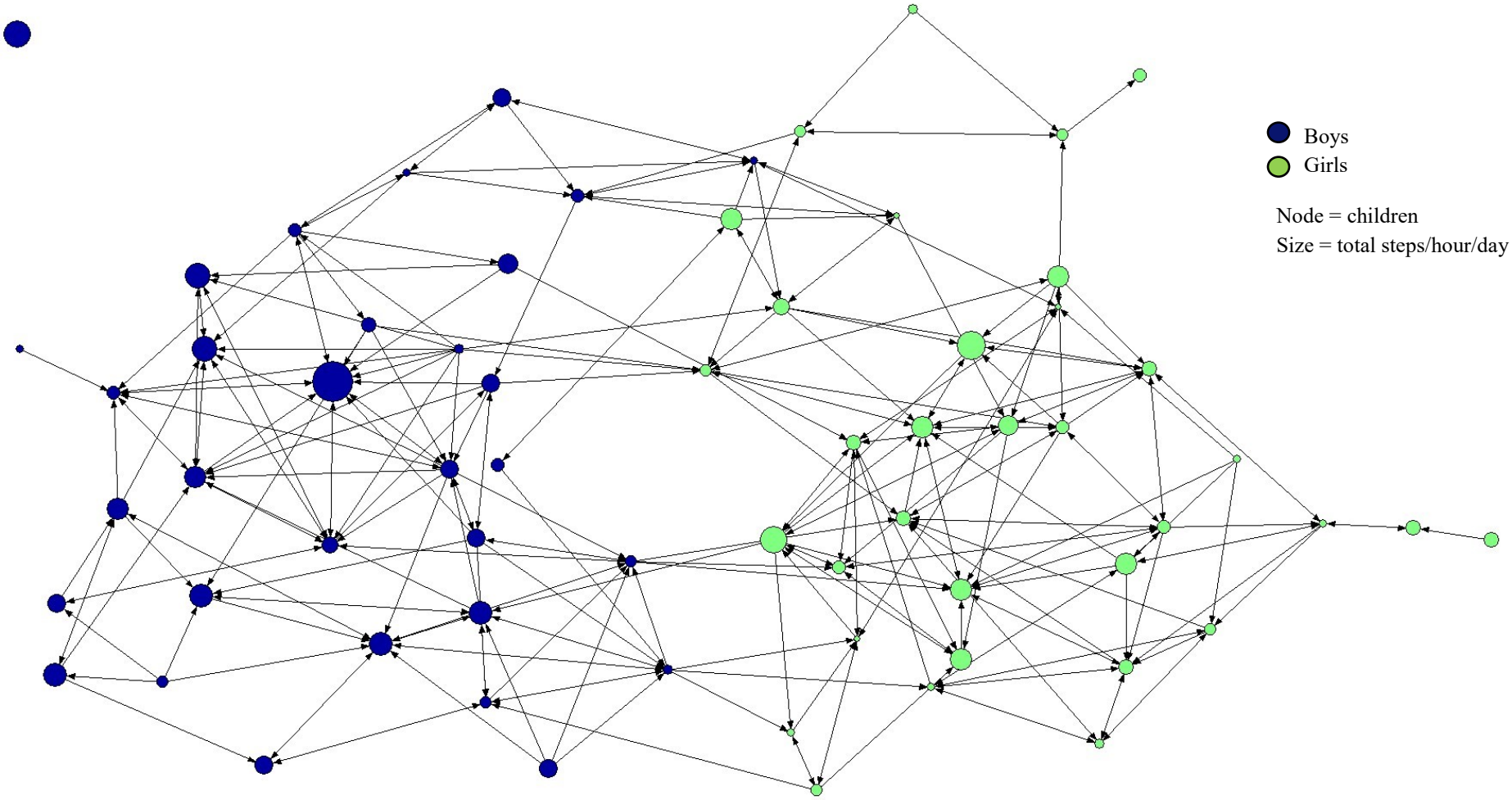

Figure 2.2. Example of a friendship network of grade 5 children from one school.

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CHAPTER 3: Study 2

An ego-network examination of friendship networks and the physical activity and screen time of grade 5 children

Jodie A. Stearns, Paul J. Veugelers, Kate Storey, & John C. Spence

Abstract

Friendships networks are important contexts for children's development and characteristics of these networks may shape their daily patterns of physical activity (PA) and screen time (ST). This study examined whether characteristics of the friendship network are associated with the pedometer-measured PA and self-reported ST of children, and differences by gender. Children (N = 801) from 32 schools participating in the APPLE Schools project (A Project Promoting healthy Living for Everyone in schools) wore pedometers for 9 consecutive days. Parents reported sociodemographic information and children reported their usual ST and perceived friendship influences (i.e., co-participation in ST, discouragement of sedentary activities, support for PA). Children also listed the first and last names of their close within-school and within-grade friendships. Social network variables, including in-degree and out-degree centrality, average friend behaviour (steps, ST), diversity of friend behaviour (steps, ST), proportion of same gender friends, and in-isolate and out-isolate status, were calculated. Path analyses controlled for clustering within schools, parent education, and child weight status. In males, friend support for PA, friend PA, and in-degree centrality were positively associated with PA, and those with in- and out-isolate status were less physically active than other children in the network. Further, screen co-participation was positively associated with ST, and friend discouragement of sedentary activities was negatively associated with ST. In females, friend PA was positively associated with PA, friend screen co-participation was positively associated with ST, and those with in-isolate status engaged in higher levels of ST than other children in the network. These findings can be used to incorporate friendship and network position components into health promotion programming.

The benefits of daily physical activity (PA) participation and limiting screen time (ST) are well established (Carson et al., 2016; Poitras et al., 2016) and reflected in evidence-based guidelines (Department of Health, 2011; Government of Australia, 2014; Tremblay, Carson, et al., 2016; US Department of Health and Human Services, 2008; World Health Organization, n.d.). Unfortunately, most children around the world do not meet PA guidelines of 60 minutes of moderate-to-vigorous physical activity (MVPA) per day (equivalent to 12,000 steps/day) or ST guidelines of less than 2 hours per day (Tremblay, Barnes, et al., 2016). In Canadian children (i.e., ages 5-11 years), 40% of males and 65% of females are insufficiently active and 30% of males and 29% of females engage in excessive ST (Roberts et al., 2017). Interventions targeting these behaviours have been successful yet the effects are small (Biddle, Petrolini, & Pearson, 2014; Metcalf, Henley, & Wilkin, 2012). Therefore, novel approaches to fostering healthy PA and ST practices in children are needed to complement and enhance current health promotion practices.

Friendships are fundamental to children's lives (Bukowski, 2001). Seminal theorizing by Henry Sullivan (1953) recognized the importance of friends in middle-to-late childhood when children develop needs for validation and interpersonal intimacy from peers (i.e., begins sometime between ~9 and 12 years of age). During this time children develop the ability to see themselves from someone else's point of view (i.e., second-person perspective) and to recognize reciprocity of thought, feelings, and actions (Selman, 1981). As a result, most children begin to form closer bonds with their peers than in earlier years, that are characterized by more mutual understanding and acceptance, and motivation to ensure each other feels connected and secure (Sullivan, 1953). Children also spend a considerable amount of time with their peers during school and in the community, including recess, lunch, and organized and active play settings.

Thus, friends may play a significant role in shaping PA during the late childhood years, which is the age group of focus for this study.

Much of the research on friends and children's PA has focused on social support, which is defined as aid and assistance provided through interpersonal interactions (Heaney & Israel, 2008). Social support in children is typically measured by co-participation in PA with friends and positive messaging around PA (e.g., encouragement), and is consistently and positively associated with child PA (Bergh et al., 2011; Ievers-Landis et al., 2003; Jago, Page, & Cooper, 2012; Silva, Lott, Wickrama, Mota, & Welk, 2012). Despite this consistent association, interactions and relationships with peers are complex and there are several other possible ways that friends could shape the PA of one another.

The association between perceived friendship variables and child ST, which could be a healthy (e.g., encourage to restrict ST) or unhealthy influence (e.g., co-participation in screen activities), have been investigated much less. Friend injunctive norms around TV viewing (i.e., perception that friends think watching TV is good or bad) and perceived friend TV viewing are associated with the TV viewing of children aged 10- to 12-years-old (te Velde et al., 2014). Though we know that children engage in plenty of ST, it is currently unknown how often this occurs with friends during late childhood. However, children also report that being physically active with friends is much more desirable than engaging in screen-based activities with friends (Jago et al., 2009), and children are less sedentary when in the presence of a friend or friends (Sanders et al., 2014). Clearly more research is needed on whether friends have a role in shaping the ST of children.

In recent years researchers have begun to use a social network approach to examine friendship network and the PA and ST of children and adolescents (Sawka, McCormack, Nettel-

Aguirre, Hawe, & Doyle-Baker, 2013). Using ego-network analysis, which examines properties of an individuals' (i.e., ego) network, we can examine how attributes of friends (e.g., average and diversity of friend PA), characteristics of interactions (e.g., co-participation in ST), and properties of the entire ego-network (e.g., network size) are associated with ego's behaviour (Borgatti, Everett, & Johnson, 2013). These measures go beyond simply asking participants about their perceptions of their friends as a whole, and instead allows us to directly measure the behaviours of friends (e.g., using activity monitors) and capture a more diverse range of potential friendship influences.

A central tenant of social network theory (SNT) is that people are influenced by, and take action in response to, their social network, including their friendship network (Valente, 2015). Thus, within the friendship context, children may choose to be friends with peers who are similarly active or engage in similar amounts of ST or, over time friends may influence one another and become similar. PA has been shown to cluster within school-based friendship groups in children (Macdonald-Wallis, Jago, Page, Brockman, & Thompson, 2011; Salway, Sebire, Solomon-Moore, Thompson, & Jago, 2018). Further, within an after school setting, children adjusted their PA over time to be consistent with their friends, yet did not select friends who were similarly active (Gesell, Tesdahl, & Ruchman, 2012). Though limited research is available on friendships and ST in childhood, one study did observe the ST of friends to be associated with initial levels of ST in females (11-12 years-old), and changes in friend ST to predict changes in ST over a 3 year period (Raudsepp & Riso, 2017). Further, research on ST and friendships in adolescents have yielded inconsistent findings (de la Haye, Robins, Mohr, & Wilson, 2010; Sawka et al., 2014).

Another tenant of SNT is that a person's position in their network influences their behaviour (Valente, 2015). Network size or centrality can be measured in different ways including number of outgoing (i.e., out-degree centrality) and incoming friendships (in-degree centrality), and a lack of or few outgoing (i.e., out-isolate status) and incoming friendships (i.e., in-isolate status). Out-degree centrality, which measures expansiveness (de la Haye, Robins, Mohr, & Wilson, 2011), is associated with self-reported MVPA outside of school hours in males, and ST in females (11-13 years-old; Marks, de la Haye, Barnett, & Allender, 2015). Though in-degree centrality, which measures social status and being well-liked (Cillessen & Marks, 2011), was not associated with PA in children (5-12 years-old; Gesell et al., 2012), it was associated with organized PA or sports in studies of adolescents (de la Haye et al., 2010). Such effects may be explained as follows: those who engage in high levels of PA and lower levels of ST may be more desirable as a friend (i.e., higher social status), and/or they may be more active because they have increased opportunities to be physically active. Also in a study of 11-15 year olds, children with no incoming friendships (i.e., in-isolate status) were less likely to meet PA guidelines than those with incoming nominations, however no associations were observed for ST (Sawka et al., 2014). Similar to above, children who are isolated may not be desired as a friend because they are inactive and engage in high levels of screen time, or being an isolate could limit opportunities to be physically active and, consequently, they are more likely to engage in screen time (Salvy, Bowker, Germeroth, & Barkley, 2012). No studies, to our knowledge, have examined the relative importance both out- and in-degree centrality and out- and in-isolate status.

Along with this, it is currently unclear what the role of same and opposite gender friendships are. It is well known that males are more active than females (Bauman et al., 2012), and research has demonstrated differences in the associations between aspects of the friendship

group and the PA and ST of males and females (de la Haye et al., 2010; Jago et al., 2009; Sawka et al., 2014). Also, differences exist in the nature of male and female friendships, with males often spending time with their friends playing sports and being physically active in peer groups, and girls spending more time talking often in dyads (Buhrmester & Furman, 1987; Rose & Smith, 2009; Zarbatany, Hartmann, & Rankin, 1990). Though same-gender friendships are more common than opposite-gender friendships (Marks et al., 2015), and consequently some research has only examined same-gender friendships (de la Haye et al., 2010; Salway et al., 2018), opposite-gender friendships do exist and may exert different influences on the PA of children than same-gender friendships. For example, considering males are more active than females it is reasonable to think that females with males as friends will be more active than females without male friends. However, Marks et al. (2015) observed that the proportion of same gender friends was associated with higher self-reported MVPA on weekends and during school breaks for males only. Alternatively, it is possible that greater influence occurs between friends who are the same gender (i.e., gender homogeneity; Valente, 2015).

Considering the importance of perceived social support from friends along with characteristics of the friendship network it is valuable to examine these variables together to determine which are the most important. Exploring interactions among friendship variables (i.e., moderation) could also provide insights. For example, it is reasonable to expect that friend PA would more strongly associate with child PA when that child is also receiving social support for PA, or friend ST would be more strongly associated with child ST when also receiving discouragement from friends for sedentary activities. Research with 14- to 15-year-olds has demonstrated best friend PA is associated with participant's PA only for emotionally close relationships (Vilhjalmsson & Thorlindsson, 1998). Interactions between general perceived

social support from friends and aspects of the friendship network have also been observed (Sawka et al., 2014).

Therefore, the purpose of this study was to examine whether characteristics of the friendship network are associated with the pedometer-measured PA and self-reported ST of grade 5 children (10-11 years-old). Specifically, we examined whether friend support for PA, friend PA, diversity of friend PA, in- and out-degree centrality, proportion of same gender friends, and in- and out-isolate status are associated with the pedometer-measured PA of children. Further, we examined whether friend discouragement of sedentary activities, friend screen co-participation, average friend ST, diversity of friend ST, in- and out-degree friendships, in- and out-isolate status, and proportion of same gender friends are associated with the ST of children. A secondary purpose was to test interactions among friendship network variables (i.e., friend PA and friend support for PA, friend PA and proportion of same gender friends, friend ST and friend co-participation, and friend ST and proportion of same gender friends) in the prediction of PA and ST. Specifically, we hypothesized that friend support for PA and friend PA would associate with PA in both males and females and that friend ST, and friend co-participation in ST would associate with ST in males and females. We further hypothesized that in-degree centrality would associate with PA in males, and that isolates would be less physically active and engage in more ST. The remainder of the examined associations was exploratory.

Methods

Participants and Procedures

Participants were grade 5 children (10-11 years-old) from Edmonton and surrounding area, and Fort McMurray, Canada who were participating in APPLE Schools (A Project Promoting healthy Living for Everyone in schools; www.appleschools.ca) in 2013. Schools from low socioeconomic status neighborhoods in Edmonton were recruited to the APPLE Schools

program (Fung et al., 2012). In Fort McMurray all schools were invited to participate. For the 2013 APPLE Schools evaluation children wore pedometers, had their height and weight measured, and completed surveys which included questions on friendship influences and ST. Parents also completed surveys which included sociodemographic information of the family. There were 42 schools who participated in the APPLE Schools evaluation, however, 9 of these schools opted not to complete the friendship portion of the survey. One additional school had too low participation rates/compliance and their observations were not considered. The analytical sample included 32 schools and 801 students. Overall the sample had comparable median household income (>$100,000/year) to rates in Alberta in 2015 ($100,130/year; Statistics Canada, 2017), and 34% of the responding parents had attained a bachelor's degree which is slightly higher than education levels in Canada (31% for males, 26% for females; Statistics Canada, 2016).

Measures

Pedometer-measured physical activity. The Omron HJ-720ITC (Ontario, Canada) piezo-electric pedometer was used to measure total PA. This time-stamped monitor records hourly steps and wear time, and stores this data for up to 42 days. As a result, children did not have to record their own steps. Evidence for the criterion validity of this model (i.e., correlation with accelerometer-measured PA r = .76-.79) as well as other Omron pedometers have been documented with children (Hart, Brusseau, Kulinna, McClain, & Tudor-Locke, 2011; Nakae, Oshima, & Ishii, 2008; Peters, Kate, & Abbey, 2013).

To account for unmeasured PA done when the pedometer was taken off, as well as non-ambulatory activities which are not accurately captured by pedometers (Tudor-Locke, 2016), we translated the step equivalent of activities recorded in logbooks and these steps were added to the crude hourly steps (Vander Ploeg, Wu, McGavock, & Veugelers, 2012). Step data from the first

and last day of measurement were removed to reduce the potential for reactivity (Lubans et al., 2015) and due to practically with device administration and pick up.

To account for differing number of valid hours between participants, PA was operationalized as steps/hour (Laurson, Welk, & Eisenmann, 2015), and was calculated by dividing average steps/day by the number of valid hours (worn or log-imputed). We only considered steps taken from 7am to 8pm on school days and 9am to 8pm on non-school days (weekends, holidays) because this is when most participants were wearing the pedometer (i.e., 70% wearing device) and because we questioned the accuracy of the proprietary wear time function after 8pm. Valid days were school days with 8 or more valid hours/day (between 7am and 8pm) and non-school days with 7 or more valid hours/day (between 9am and 8pm) which is consistent with other pedometer studies that required participants to have worn the device for ~60% of the day (Peters et al., 2013; Vander Ploeg et al., 2012). Participants with 2 or more valid days were included (Craig, Tudor-Locke, Cragg, & Cameron, 2010; Rowe, Mahar, Raedeke, & Lore, 2004). Though the inclusion of a weekend day is often required due to low activity on the weekends (Lubans et al., 2015), no differences were detected in steps/hour between school days and non-school days using a paired samples *t*-test ($t[687] = -.09$, $p = .93$) and thus was not required in this study. Days with >50% of hours having 0's were removed.

Child-reported screen time. Child-reported ST was assessed with the question "Usually, how many hours per day do you spend on the following activities outside of school hours?" a) using a computer, b) playing video games, c) watching TV, and d) using a cell phone, tablet or iPad. Responses include "less than 1 hour a day", "1-2 hours a day", "3-4 hours a day" and "5 or more hours a day". Consistent with previous research, total ST (hours/day) was calculated by taking the midpoint of each person's response (i.e., .5, 1.5, 3.5, 5.5) and summing the three values

(Carson et al., 2010). These questions are similar to the Child Sedentary Activity Questionnaire (CSAQ) which has evidence of acceptable reliability (two week test-retest ICC = .98) and validity (correlation with activity diary ICC = .5-.8; He, Harris, Piché, & Beynon, 2009).

Friendship network variables. Each student provided the first and last name of up to 10 close friends in their school and grade, which were defined as "other children you hang around with, talk to, and do things with the most" (de la Haye et al., 2010; de la Haye et al., 2011). Children were considered friends if one student nominated the other as a friend; thus, both incoming and outgoing friendship nominations were included. *Friend PA/ST* and *dispersion of friend PA/ST* were the average and standard deviation of the PA (steps/hour) and ST (hours/day) of each close friend. Students had to have at least one friend to receive an average or diversity of friend behaviour score. *In-degree centrality* was the number of friends who nominated the ego as a friend, and *out-degree centrality* was the number of friends whom the ego nominated as a friend. Though in-degree centrality is often described as a measure of popularity (Hawe, Webster, & Shiell, 2004), researchers in developmental psychology regard popularity as a highly related but slightly different concept (i.e., prestige, power, and visibility among peers; Cillessen & Marks, 2011). As such, we consider in-degree centrality as an indicator of social status and being well liked instead. The proportion of opposite gender friendships was also calculated. Finally, children were regarded as *in-isolates* if they had none or only one incoming friendship nomination and *out-isolates* if they had none or only one outgoing friendship nomination which is consistent with social network research on smoking (Choi & Smith, 2013). Though a complete census approach was taken to the collection of friendship tie information, an ego-network approach was employed to summarize friendship network characteristics because it enabled us

examine both social network characteristics and perceived friendship influence variables in the same model.

Perceived friendship influence. Students were asked "During a typical week, how often do your friends… a) encourage you to do sports or physical activities?, b) do physical activity or play sports with you?, c) ask you to walk or bike to school or to a friend's house?, d) tell you that you are doing well in physical activities or sports?, e) do sedentary activities like watch TV or play computer/video games with you? and, f) do your friends encourage you to spend less time being sedentary? Response options included "never", "1-2 days", "3-4 days", "5-6 days", and "every day". The friend support for PA questions (a-d) and friend sedentary activity questions (e-f) were obtained from the Patient-centered Assessment and Counseling for Exercise (PACE) adolescent questionnaire (Norman, Schmid, Sallis, Calfas, & Patrick, 2005). Internal consistency (α = .60-.75), 1-week test-retest ICC = .68; 5-item scale [includes a question on peer teasing in PA settings]) were reported with 11- to 15-year-olds. With grade 6 to 8 students in the US, strong test-retest reliability (ICC = .86), good internal consistency (α = .81), and evidence of convergent validity (i.e., parent and child reports, r = .57, $p < .01$; correlations with self-reported MVPA, r = .22-.29) have been reported for a 4-item PA peer support scale (frequency child encourages friends to be active replaced walk or bike to school with*;* Prochaska, Rodgers, & Sallis, 2002). In our study, the internal consistency for friend support for PA was α = .76. Norman et al. (2005) reported the internal consistency of the sedentary activity questions to be low (α = .48-.58; ICC = .77; three-item scale), and we observed a low correlation between the 2 items (r = .10, $p < .01$). Therefore, they were used as single-item questions and were recoded as days per week by taking the midpoint of each person's response (i.e., 0, 1.5, 3.5, 5.5, 7).

Demographics. Students reported their own gender. Weight and height were measured using a calibrated scale (nearest 0.1 kg) and stadiometer (nearest 1.0 mm). Body mass index (BMI) *z*-scores were categorized into *healthy weight* (*z*-score below 1) and *overweight/obese* (*z*-score greater than or equal to 1) based on the World Health Organizations (WHO) growth reference (de Onis et al., 2007; World Health Organization, 2007). A parent indicated their highest level of education (response options: no schooling, elementary, secondary, community/technical college, university, and graduate university), household income (response options: less than $25,000, $25,001-$50,000, $50,001-$75,000, $75,001-$100,000, more than $100,000 and don't know/prefer not to answer), and whether they were born in Canada (yes/no).

Analysis

Preliminary analysis was completed in IBM SPSS 25, friendship network variables were created in UCINET 6 (Borgatti, Everett, & Freeman, 2002), and path analysis was completed in MPlus (Muthen & Muthen, 1998-2012). Data were checked for univariate and multivariate normality, linearity, and homoscedasticity (Kline, 2011). Daily pedometer steps <1,000 were deleted and >30,000 were truncated (Lubans et al., 2015). For the summary variables, outliers were identified as a *z*-score < -3.29 or >3.29 (Tabachnick & Fidell, 2007) and truncated (ego PA $n = 5$; friend PA $n = 3$; diversity of friend PA $n = 1$, ego ST $n = 8$, diversity of friend ST $n = 2$, in-degree centrality $n = 3$). Multivariate outliers were identified as studentized deleted residuals < -3 or > 3 and were deleted (ego steps analysis n = 12; ST analysis n = 23; isolate analysis n = 35). ICC's for ego PA were 0.12 for females and 0.13 for males and ICC's for ST were 0.04 for females and 0.02 for males, suggesting that controling for clustering within schools was required.

A measurement model was run for friend social support to ensure model fit. Measurement invariance for gender (i.e., configural, metric, scalar invariance, equal residuals)

was tested by setting equality constraints between gender one by one (i.e., factor loadings, intercepts, and residuals) and testing for significant differences between nested models.

Three separate analyses were completed using path analysis in Mplus controlling for clustering within schools, parent education, and child weight status. The first analysis included in- and out-degree friendships, friend PA, diversity of friend PA, and friend social support for PA as predictors of ego PA. Multiple group path analysis tested for differences between males and females by setting the pathways as equivalent between females and males (except the covariates) and assessing model fit between constrained and unconstrained models (Kelloway, 2015). Interactions were tested for friend PA and friend support for PA, and friend PA and proportion of same gender friends. The second analysis included in- and out-degree centrality, friend ST, diversity of friend ST, friend screen co-participation, and friend discouragement of sedentary activities as predictors of ego ST. Interactions were tested for friend ST and friend screen co-participation, and for friend ST and proportion of same gender friends. The third analysis included in- and out-isolate status as the predictor variable of ego PA and ego ST. Interactions were tested by adding interaction terms to the models one-by-one. Interactions involving latent variables (i.e., friend support for PA) were completed using the XWITH function in MPlus and TYPE = Random. All observed continuous variables were centered for the interactions. For significant interaction terms simple slopes were calculated by centering one variable from the interaction on meaningful values (e.g., low, average, high scores) and observing changes in the beta coefficient of the second variable. All analyses used the maximum likelihood estimator with robust standard errors (MLR) estimator to account for some skewed distributions, and controlled for clustering within schools, child weight status, and parent

education. Due to the large sample and complexities of conducting such an analysis, dependencies between egos who share friendship ties were not accounted for.

The default settings in MPlus were used to deal with missing data. Specifically, MPlus removes cases that have missing data on observed x-variables including predictor variables, covariates, and stratification variables (i.e., gender). For the PA analysis, cases with complete data on x-variables yet missing data on ego steps (12% missing) or friend support indicator(s) (latent variable; <1% missing) were estimated using full information maximum likelihood (FIML). For the ST analysis, data missing on ego ST (n = 5) were excluded. Further, for the PA and ST analyses, children without incoming or outgoing friendships (n = 9) were excluded because they had no friendship data to contribute. For the isolate analysis, data missing on both ego steps and ego ST were removed (n = 2) and any cases with missing data on just one criterion variable was estimated using FIML (12% missing on ego steps, <1% missing on ego ST). Those who were missing data on ego steps differed from those who were not missing on ego steps for out-degree friendships ($p < .05$) and in-degree centrality ($p < .01$), and thus the data appears to be at least partially missing at random (MAR). When data is MAR, FIML is a powerful technique that produces unbiased estimates and fit statistics (Enders & Bandalos, 2001).

Because the PA analyses included a latent variable for friend social support for PA, model fit statistics were available. Absolute model fit was determined by a non-significant χ^2 or a χ^2/df value of ≤ 3 (Iacobucci, 2010) along with RMSEA (acceptable fit ≤ .06), CFI (acceptable fit ≥ .95), and SRMR (acceptable fit ≤ .08; Hu & Bentler, 1999). Significant worsening of model fit between nested models for the measurement and structural invariance testing was determined by a significant Satorra-Bentler scaled $\Delta\chi^{2\ \text{difference}}$ test (Muthen & Muthen, 2005) and a ΔCFI of

> .01 (measurement invariance only; Cheung & Rensvold, 2002). Significance was set at $p < .05$ for all analyses, both unstandardized (B) and standardized (β) path coefficients are presented.

Results

Descriptive statistics are presented in Table 3.1. Males (M = 867 steps/hour, SD = 290) took significantly more steps than females (M = 749 steps/hour, SD = 237). Males (M = 6.23 hours/day, SD = 3.66) engaged in significantly more ST than females (M = 5.29 hours/day, SD = 3.07). On average, males had 4.27 (SD = 2.37) outgoing close friends and 4.33 incoming close friends (SD = 2.70), 87% of which had valid step data and 98% of which had valid ST data. The friends of males took 860 steps/hour (SD = 168) and engaged in 6.00 (SD = 1.89) hours/day of ST. On average, females had 4.69 outgoing close friendship (SD = 2.26) and 4.64 incoming close friendships (SD = 2.53), 90% of which had valid step data and 97% of which had valid ST data. The friends of females took 765 steps/hour (SD = 134) and engaged in 5.32 hours/day of ST (SD = 1.56). Friend support for PA, friend steps, diversity of friend steps, friend ST, diversity of friend ST, friend discouragement of sedentary activities, and friend screen co-participation were significantly higher in males than females. Number of outgoing friendships was higher in females than males, but no significant difference existed for incoming friendships.

Measurement model. A one-factor model achieved model fit (χ^2 [2] = 1.93, p = .38, RMSEA = 0.00, CFI = 1.00, SRMR = 0.01). Measurement invariance across gender was achieved for configural, metric, scalar, and equal residuals, therefore, males and females can be directly compared on this variable. Standardized factor loadings ranged between 0.46 and 0.79 (all p's < .01) for females and between 0.51 and 0.76 (all p's < .01) for males (see Table 3.2).

Physical Activity. The multiple-group path analyses with characteristics of the friendship network predicting ego PA had a good fit to the data (χ^2 = 82.38 [72], p = .19; RMSEA = 0.02;

CFI = 0.99; SRMR = 0.04). When the model was set as equal between males and females there was also a good fit to the data (χ^2 = 90.09 [78], p = .16; RMSEA = 0.02; CFI = 0.99; SRMR = 0.04), and was not significantly worse than the unconstrained model ($\Delta \chi^2$ [6] = 7.62, *ns*). However, some gender differences existed in terms of significance of path coefficients and thus we present the results separately by gender.

For females, friend steps and ego weight status were associated with ego steps (13% of the variance explained; see Table 3.3). For every additional 100 step/hour taken by a female's friends she took an additional **47** steps/hour (B = 0.47 ± 0.09, p < .01). For males, perceived friend support for PA, friend steps, in-degree centrality, and ego weight status were associated with ego steps (20% of the variance explained). For every additional 1 unit in friend support males took an additional **71** steps/hour (B = 71.40 ± 14.85, p < .01), for every additional 100 step/hour taken by a male's friends he took an additional **43** step/hour (B = 0.43 ± 0.10, p < .01), and for every one additional incoming friendship males took an additional **20** steps/hour (B = 19.75 ± 5.63, p < .01). No significant interactions were observed between friend support for PA and friend PA for females (B = 0.08 ± 0.11, p = .48) or for males (B = -0.02 ± 0.07, p = .78), or between friend steps and same gender for females (B = -0.13 ± 0.17, p = .44) or males (B = -0.15 ± 0.20, p = .44).

Screen Time. The multiple-group path analyses with characteristics of the friendship network predicting ego ST (see Table 3.3) was just identified and thus model fit statistics were not available. For females, friend screen co-participation was the only variable significantly associated with ego ST (16% explained variance). For every 1 additional day of friend screen co-participation, females engaged in an additional **31** minutes/day of ST (B = 0.51 ± 0.11, p < .01). For males, friend discouragement of sedentary activities and friend screen co-participation were

significantly associated with ego ST (15% explained variance). For every one additional day that males received discouragement of sedentary activities from their friends they engaged in **10** less minutes/day of ST (B = -0.16 ± 0.06, $p < .05$), and for every one additional day they co-participated in screen activities with their friends, males engaged in an additional **29** minutes/day of ST (B = 0.48 ± 0.08, $p < .01$). An interaction was found between friend ST and discouragement of sedentary activities for females (B = 0.08 ± 0.03, $p = .01$) but not for males (B = 0.01 ± 0.04, $p = .70$). Specifically, for females, the association between friend and ego ST was significant at higher levels of discouragement of sedentary activities (no discouragement, B = -0.03 ± 0.15, $p = .85$; discouragement 3-4 days/week, B = 0.24 ± 0.16, $p = .12$; discouragement every day, B = 0.51 ± 0.22, $p = .02$). Thus, for females whose friends encouraged them to limit their ST every day, for every 60 minute decrease in friends ST she engaged in **31** less minutes/day of ST. No interaction was found between friend ST and friend screen co-participation for females (B = 0.05 ± 0.05, $p = .32$) and males (B = -0.02 ± 0.04, $p = .68$), or for friend ST and same gender for females (B = 0.19 ± 0.20, $p = .34$) and males (B = -0.27 ± 0.19, $p = .16$).

Isolate analysis. The multiple-group path analyses with in- and out-isolate status predicting ego PA and ST (see Table 3.4) was just identified and thus model fit statistics were not available. For females, in-isolate status was associated with ego ST (B = 1.13 ± 0.53, $p = .03$), such that in-isolates engaged in **68** more minutes of ST per day than those with two or more incoming friendships. For males, out-isolate status (B = -89.70 ± 43.69, $p = .04$) and in-isolate status (B = -80.75 ± 38.70, $p = .04$) were both associated with ego steps, such that out-isolates took **90** steps/hour less than those with 2 or more outgoing friendship nominations, and in-isolates took **81** steps/hour less than those with 2 or more friendship nominations.

Discussion

The purpose of this study was to examine whether characteristics of the friendship network are associated with the pedometer-measured PA and self-reported ST of children, and differences by gender. This study was novel as it included both perceptions of friend support for PA and social network variables, and focused on the late childhood years, a time when friends are theorized to increase in importance in children's lives (Sullivan, 1953). As hypothesized, friend support for PA, friend PA, and in-degree centrality were significantly and positively associated with ego PA in males. However, in females, only friend PA was significantly associated with ego PA. Further, friend screen co-participation was positively associated with ego ST in both males and females, and friend discouragement of sedentary activities was negatively associated with ego ST in males. An interaction was also observed between friend ST and friend discouragement of sedentary activities, such that for females who received daily discouragement of sedentary activities from friends, low friend ST was associated with low ST. Finally, in-isolate status was associated with higher ST in females and in- and out-isolate status were associated with lower PA in males. These findings demonstrate that characteristics of children's friendship networks, or the lack thereof, are important correlates of their PA and ST.

The observed association between friend PA and ego PA in both females and males is consistent with the wider friendship and social network literature with children and adolescents which shows a consistent association between these variables (Maturo & Cunningham, 2013; Sawka et al., 2013). For example, in two studies of children, there was clustering of accelerometer-measured MVPA and total PA within children's friendship networks (Macdonald-Wallis et al., 2011; Salway et al., 2018). An interesting finding from our study, however, was the magnitude of effect was similar for males and females with a 100 step/hour increase in friend

steps being associated with a 47- and 43-step/hour increase in ego steps, respectively. Effects amount to between 376-611 extra steps/day in females and 344-558 extra steps/day in males. These findings deviates from Salway et al. (2018) who observed stronger clustering of MVPA for males (autocorrelation = 0.21) compared to females (autocorrelation = 0.14; 8-9 year-olds), and Jago et al. (2011) who observed a significant association between the accelerometer-measured MVPA of male best friend dyads but not females (or for total PA in either gender; 10-11 year-olds). Several differences between studies could explain the discrepancy. For example, Jago et al. only included the PA of 1 best friend, whereas our study included the PA of all close friends which represents the wider group of friends. Further, Salway et al. used spatial autoregressive modeling to examine clustering of PA among friendship networks which is a very different from our ego-network analysis which summarized PA levels across friends. Our findings are consistent with an ego-network studies of older participants (10-to-16 years-old) whereby a higher proportion of active friends was associated with a higher odds of meeting PA guidelines in both males (OR = 1.11) and females (OR = 1.14; Sawka et al., 2014). Despite the variety of friendship and PA measures and analytic methods used, our study along with others suggest that the PA of friends could shape children's PA, possibly through modeling processes (Salvy, De La Haye, Bowker, & Hermans, 2012). However it is also possible that children simply select friends who are similarly active or who participate in similar physical activities. Longitudinal research in childhood and early adolescence have shown that influence plays a larger role than selection (de la Haye et al., 2011; Gesell et al., 2012).

To the contrary, friends' ST was not an important correlate of ST for males or females in the main analyses. The lack of association may be due to some screen-activities being commonly done in the home where friends are often not present (e.g., TV viewing, video games). However,

for females who received daily discouragement from friends for sedentary activities, those whose friends engaged in low ST also had low ST levels. Thus, for females, the modeling of ST restriction by friends may not be enough to impact children's behaviour, and only when paired with frequent discouragement does a friend's behaviour become influential. However it is also possible that children who value limiting ST both seek out friends who engage in low levels of ST and who support their ST limits. Research on this topic is sparse, particularly in the childhood years (Sawka et al., 2013). In an older sample (11-15 year-olds), Sawka et al. (2014) did not find associations between proportion of sedentary (> 2 hours ST/day) friends and the odds of meeting ST guidelines. Another observed friends' ST to be associated with ST in males (B = 0.24) in middle- and high-school students (M_{age} = 14.5 years-old; Garcia, Sirard, Deutsch, & Weltman, 2016). Considering the lack of studies to compare to in the late childhood years, we conclude that the ST behaviour of friends can discourage ST for females when paired with daily discouragement from friends for limiting ST.

Previous studies have observed consistent associations between friend support for PA and the PA of children in late childhood, yet few have examined gender differences (Bergh et al., 2011; Ievers-Landis et al., 2003; Silva et al., 2012). In our study, for every 1 unit increase in friends support (5-unit scale), males took an additional 71 steps/hour which amounts to between 568 and 923 additional steps/day. Jago et al. (2012) observed an association between friend support for PA and weekday MVPA for males aged 10- to 11-years-old but not females. Interestingly however after the transition to secondary school (1 year later) friend support for PA was related to MVPA in both males and females, yet change in friend support for PA across this year was only associated with change in MVPA for females. Therefore, it is possible that friend support for PA becomes more important for females over time. One potential reason for the non-

significant findings for social support in females is that many parents afford females less independent mobility than males (Riazi & Faulkner, 2018), which means they have fewer opportunities to play and socialize with peers (Prezza et al., 2001), and many have to rely on their parents to supervise them.

We are unaware of any other studies of perceived friend screen co-participation and discouragement of sedentary activities apart from research reporting on the psychometrics of the PACE questionnaire (Norman et al., 2005). However, parents of younger children (5-6 years-old) think their friends influence the shows they choose to watch and the online games they ask to play, which could be due to co-participation and/or discussions about these shows or games (Edwards et al., 2015). Time spent with friends is also negatively associated with TV viewing (Vandewater, Park, Hébert, & Cummings, 2015), and children prefer to be active rather than sedentary with friends (Jago et al., 2009). Thus, friends appear to influence the ST of children in both healthy and unhealthy ways. In our study, co-participation in ST activities with friends was associated with ST in both females and males with an additional day of co-participation in ST per week being associated with 31 more minutes/day of ST in females and 29 more minutes/day of ST in males. Friend discouragement of sedentary activities was a correlate of ST in males such that for every 1 additional day of sedentary activity discouragement they engaged in 10 less minutes/day of screen time. Despite the limited research to compare with, in late childhood, participating in screen activities with friends does appear to support ST in unhealthy ways whereas friend discouragement of sedentary activities supports ST in healthy ways.

Considering the previously mentioned findings on the importance of friends in understanding PA and ST habits of children, schools, parents, and health promotion specialists should be made aware of the powerful impact that friends may have on children. Strategies can

then be developed that empower children and their friends to support one another's healthy behaviour and role model healthy living for one another. For example, messages can covey that PA is fun to do with friends, education and tools can be provided on how to seek and give support for healthy living, and programming can incorporate learnings on cooperation and building friendships within PA games. ST co-participation among friends can also be discouraged through school policies around screen use at school, and by parent's rules around screen use with friends.

We found that the most well liked males (i.e., in-degree centrality) were more physically active than other males, such that for every 1 additional incoming friendship nomination, males took 20 additional steps/hour. This equates to a difference of 1,600-2,600 steps/day between males with no friends and 10 friends, which is a substantial effect. This is consistent with qualitative research showing that athletic ability is a social status symbol in male friendship groups in childhood (age 10-11 years; Jago et al., 2009). Yet for females PA ability was desirable in some female groups but not others. The quantitative findings however are inconsistent. A study 13- to 14-year-olds observed receiver effects for organized PA (i.e., equivalent to in-degree centrality) in both males and females (de la Haye et al., 2010). A study of 11- to 15-year-olds in Canada, however did not observe in-degree centrality to be associated with meeting PA guidelines in males or females (Sawka et al., 2014), and a study of 5-12 year-olds in an after school program did not observe receiver effects in a gender combined sample (Gesell et al., 2012).

One common social network intervention (i.e., opinion leader intervention) involves recruiting the most well-liked people in a network, training them on a topic, and asking them to informally spread healthy behaviours and ideas to the people in that network (Valente, 2012).

The idea is that the most central individuals are the most influential in terms of shaping the attitudes and behaviour of others in the network. However, as the most well-liked males in this study are already the most active, they will already be modeling high levels of PA for their peers. As such, they may not be the best targets and recruiting "opinion leaders" in different positions in the network (e.g., those connected to multiple groups) could be more effective. For females, considering the most well-liked children do not appear to be the most active, recruiting well liked females to help informally change behaviours and attitudes in the network via modeling, encouragement, and education, may be effective. In support of this, two opinion leader interventions in males and females that recruited students with high scores on several relational variables (e.g., leadership, friendship, look up to, respect) were unsuccessful in changing the PA levels of adolescents (Bell, Audrey, Cooper, Noble, & Campbell, 2017; van Woudenberg et al., 2018), whereas an intervention focused on females specifically did (Sebire et al., 2018).

A concerning finding was that isolated males were less physically active than non-isolated males (in- and out-isolate status) and isolated females engaged in more ST than non-isolated females (in-isolate status). Specifically, there was a difference of 68 minutes/day of ST between in-isolates and other females in the network. Similarly, there was a difference of 90 steps/hour between out-isolates and other males (equates to 720-1,170 steps/day), and a difference of 81 steps/hour between in-isolates and other males (equates to 640-1,053 steps/day). These effects are very large and concerning. Considering the mental health risks of being isolated (Hall-Lande, Eisenberg, Christenson, & Neumark-Sztainer, 2007) along with the risk for unhealthy PA for males and unhealthy ST for females, these children could be considered most "at risk" and should be prioritized. This recommendation is consistent with a study that simulated three scenarios of network change within a real-world after school program.

Specifically, they simulated the increase in PA of the most central children, random children, or the most sedentary children as well as the ripple effect on the PA levels of the remainder of the children in the network (Zhang, Shoham, Tesdahl, & Gesell, 2015). Although the opinion leader intervention (i.e., increase PA of children with highest in-degree centrality) was the most effective at increasing behaviours of the entire network, the simulation showed that this approach not reach the most sedentary children who were the most in need (Tsai et al., 2016; Zhang et al., 2015). As a consequence, these children likely require separate health promotion strategies than the wider population of children in schools. For example, friend benches at schools can help ensure that all children have someone to play with (Kill It With Kindness, n.d.). Also, these children could receive training to help build the skills they need to develop meaningful friendships (e.g., cooperation, respectfulness), and all children should learn about the importance of inclusion and acceptance of others to ensure that no one is left out. Though it is possible these children have friends outside of school or grade level, having few or no friends at school does seem to impact the PA of males or the ST of females.

This study has several strengths. First, we measured several aspects of the friendship network both directly from friends and as perceived by the ego. This allowed us to capture a wide range of possible influences from friends including both perceived social support from friends, which is a consistent correlate of PA in children and adolescents (Maturo & Cunningham, 2013), and mean levels and diversity of friend PA and ST, as well as number of incoming and outgoing friendship nominations (i.e., in- and out-degree centrality), and in- and out-isolate status. Second, we included a relatively large sample of schools from a wide range of sociodemographic backgrounds which increases the generalizability of our findings and allowed us to examine multiple-group models comparing males and females. Third, the PA of all

children, including the ego's and their friends, were measured objectively using pedometers, which is more accurate than self-report measures in measuring ambulatory total activity throughout the day. Non-ambulatory and non-wear activities were also imputed to account for activities that the pedometer measure which allowed us to more accurately capture the PA performed by the children. Fourth, we used path analysis which allowed us to model both PA and ST as outcome variables in the isolate analysis and include friend support as a latent variable in the friendship and PA analysis. Finally, our ST survey included use of modern screen devices (i.e., ipads, tablets, and cell phones) that have become very popular in recent years yet are often not captured.

This study is not without limitations. Because it is cross-sectional we cannot know for sure whether aspects of the friendship network influence children's behaviour. Consistent with social cognitive theory which describes triadic reciprocal determinism between behaviour, person (i.e., cognitions, affect, biology), and the environment (Bandura, 1989), it is likely that bidirectional influences occur. For example, friends' encouragement for PA (environment) may lead to persistence in being physically active, or children who are more active may seek friends that support their participation in their chosen PA or sport. The children were also participating in a comprehensive school health program (i.e., APPLE Schools) that has been shown to increase PA levels (Fung et al., 2012; Vander Ploeg, McGavock, Maximova, & Veugelers, 2014) and thus the findings may not generalize to schools without supports for healthy living. Regardless, many children are still insufficiently active (i.e., only 21% of females and 34% of males accumulated 12,000 steps/day [equivalent to 60 minutes of MVPA/day]) and therefore there is still room for improvement. Also, ST was self-reported by the children which is known to introduce measurement error due to poor memory recall, low motivation, and socially desirable responses

(Hardy et al., 2013). These are the prominent measures of ST however in the literature (Lubans et al., 2011), and limited other options are available currently for large scale studies. Future research is needed examining why friends may influence the PA and ST of children (i.e., the mechanisms), and tracking friendship factors and children's behaviour across the childhood to adolescent years to uncover when friends become significant influence agents.

In summary, this research suggests that friends may be an important source of influence on PA and ST in late childhood. The findings can be used to incorporate friendship-focused components into health promotion programming within schools and communities. Strategies for targeting children in specific positions in the network are also worthwhile.

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Table 3.1

Descriptive information for grade 5 children participating in the APPLE Schools program in 2013

	n	Males	Females
Physical activity variables – mean (SD)			
Ego total steps/hour	682	849 (268)	741 (221)**
Friend steps/hour	773	861 (170)	763 (132)**
Diversity of friend steps/hour+	773	208 (108)	172 (94)**
Sedentary activity variables – mean (SD)			
Ego screen time hours/day – median (mean rank)	757	5.00 (405.65)	4.00 (353.52)**
Friend screen time hours/day – mean (SD)	757	6.00 (1.88)	5.31 (1.57)**
Diversity of friend screen time – mean (SD)	757	2.61 (1.27)	2.42 (1.32)*
Friend discouragement (0-4) – median (mean rank)	757	1.50 (460.50)	1.50 (424.83)*
Friend co-activity (0-4) – median (mean rank)	757	1.50 (491.51)	1.50 (392.00)**
Friendship variables			
No. of outgoing friends – mean (SD)	801	4.27 (2.37)	4.69 (2.26)*
No. of incoming friends – mean (SD)	801	4.33 (2.70)	4.64 (2.53)
Same gender friends – count (%)	792		
All same gender		219 (56.7)	235 (57.9)
≥ 1 opposite gender		167 (43.3)	171 (42.1)
Out-isolate status	801		
0-1 friends		47 (12.0)	32 (7.8)*
> 1 friends		344 (88.0)	378 (92.2)
In-isolate status	801		
0-1 friends		52 (13.3)	39 (9.5)
> 1 friends		339 (86.7)	371 (90.5)
Demographic variables			
Parent education – count (%)	801		
Secondary or less		110 (28.1)	100 (24.4)
College		153 (39.1)	165 (40.2)
University		80 (20.5)	78 (19.0)

Graduate university		48 (12.3)	67 (16.3)
Household income – count (%)	518		
<$25,000		14 (5.3)	15 (5.9)
$25,000-$50,000		31 (11.7)	32 (12.6)
$50,001-$75,000		26 (9.8)	32 (12.6)
$75,001-$100,000		36 (13.6)	27 (10.6)
>$100,000		157 (59.5)	143 (58.3)
Parent born in Canada – count (%)	789		
No		87 (22.4)	143 (34.9)**
Yes		301 (77.6)	267 (65.1)

Note. Differences between males and females were tested using independent samples *t*-tests for all PA variables, friend screen time, diversity of friend screen time, no. incoming friendships, no. outgoing friendships, using Mann-Whitney U tests for ego screen time, friend discouragement and co-activity of sedentary activities, and a chi-square test of independence for same gender, in- and out-isolate status, parent education, household income, and parent born in Canada; *$p < .05$; **$p < .01$; + Calculated as the standard deviation of the mean steps/hour across friends.

Table 3.2

Factor loadings for friend support for physical activity

	Females				Males			
	Mean	Variance	Standardized Factor Loading	Error Variance	Mean	Variance	Standardized Factor Loading	Error Variance
Friend Support								
Encouragement (0-4)	1.57	1.6	0.69	0.53	1.73	1.84	0.76	0.43
Co-participation (0-4)	1.98	1.58	0.66	0.57	2.16	1.68	0.76	0.42
Active transportation (0-4)	1.25	1.67	0.46	0.79	1.32	1.81	0.51	0.74
Praise (0-4)	1.73	1.76	0.68	0.56	1.87	1.86	0.74	0.46

Table 3.3

Association between characteristics of the friendship group and the screen time and physical activity of grade 5 children participating in the APPLE Schools program

	Females				Males			
	B (SE)	*p*-value	β (SE)	R^2	B	*p*-value	β (SE)	R^2
Screen Time (hours/day)				0.16				0.15
Friend screen discouragement	-0.08 (0.06)	.23	-0.06 (0.05)		-0.16 (0.06)	.02	-0.11 (0.05)	
Friend screen co-participation	0.51 (0.11)	<.01	0.34 (0.07)		0.48 (0.08)	<.01	0.33 (0.06)	
Friend mean screen time	0.09 (0.14)	.52	0.05 (0.08)		0.18 (0.11)	.10	0.11 (0.07)	
Friend diversity of screen time	0.17 (0.16)	.28	0.08 (0.08)		-0.26 (0.14)	.08	-0.10 (0.06)	
Out-degree centrality	-0.02 (0.06)	.78	-0.02 (0.05)		-0.06 (0.10)	.54	-0.04 (0.07)	
In-degree centrality	-0.11 (0.07)	.14	-0.10 (0.07)		-0.03 (0.06)	.60	-0.03 (0.05)	
Same gender*	-0.16 (0.26)	.53	-0.03 (0.05)		-0.25 (0.33)	.45	-0.04 (0.05)	
Weight status	0.38 (0.22)	.08	0.07 (0.04)		0.25 (0.30)	.40	0.04 (0.05)	
Parent education	0.04 (0.12)	.76	0.01 (0.05)		-0.10 (0.15)	.49	-0.03 (0.05)	
Physical Activity (steps/hour)				0.13				0.20
Friend support for PA	25.79 (14.64)	.08	0.10 (0.06)		71.40 (14.85)	<.01	0.28 (0.06)	
Friend steps	0.47 (0.09)	<.01	0.28 (0.05)		0.43 (0.10)	<.01	0.27 (0.06)	
Diversity of friend steps	0.00 (0.14)	1.00	0.00 (0.06)		-0.18 (0.16)	.24	-0.08 (0.06)	
Out-degree centrality	-1.87 (4.11)	.65	-0.02 (0.04)		-10.60 (7.63)	.17	-0.10 (0.07)	
In-degree centrality	6.72 (5.60)	.23	0.08 (0.06)		19.75 (5.63)	<.01	0.20 (0.06)	
Same gender*	-22.97 (24.56)	.35	-0.05 (0.06)		-29.56 (37.64)	.43	-0.06 (0.07)	

Ego weight status	-57.28 (18.42)	<.01	-0.13 (0.04)	-54.63 (23.36)	.02	-0.10 (0.04)
Ego parent education	-8.23 (11.90)	.49	-0.04 (0.06)	1.42 (11.05)	.90	0.01 (0.04)

Note. PA = physical activity; *coded as 0 = some opposite gender friends, 1 = all same gender friends; unstandardized beta coefficient (B) and standardized beta coefficient (β)'s and standard errors are presented; model fit for the PA model: $\chi^2 = 82.38$ [72], $p = .19$; RMSEA = 0.02; CFI = 0.99; SRMR = 0.04; Path analysis models for screen time were fully identified and thus model statistics were not available; screen time analysis females $n = 387$, males $n = 370$; PA analysis females $n = 400$, males $n = 373$.

Table 3.4

Association between in- and out-isolate status and the physical activity and screen time of grade 5 children participating in the APPLE Schools program

	Females (*n* = 395)			Males (*n* = 371)		
	B (SE)	*p*-value	R^2	B (SE)	*p*-value	R^2
Physical Activity (steps/hour)			0.02			0.05
Out-isolate	0.79 (60.73)	.99		-89.70 (43.69)	.04	
In-isolate	5.44 (50.65)	.92		-80.75 (38.70)	.04	
Ego weight status	-59.99 (19.39)	<.01		-74.08 (23.10)	.01	
Ego parent education	-11.67 (12.32)	.34		-4.68 (13.80)	.73	
Screen Time (hours/day)			0.02			0.04
Out-isolate	-0.33 (0.55)	.55		0.97 (0.79)	.22	
In-isolate	1.13 (0.53)	.03		1.20 (0.62)	.05	
Ego weight status	0.25 (0.24)	.31		-0.01 (0.30)	.98	
Ego parent education	0.07 (0.12)	.59		-0.14 (0.17)	.41	

Note. Out-isolate coded as 0 = non-isolate (> 1 outgoing friendships) = 0, isolate (≤ 1 outgoing friendships) = 1; in-isolate coded as 0 = non-isolate (> 1 incoming friendship), isolate (≤ 1 incoming friendships); unstandardized path coefficients and standard errors are presented.

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CHAPTER 4: Study 3

Enjoyment and self-efficacy for physical activity as mediators of the friendship network and children's physical activity

Jodie A. Stearns, Paul J. Veugelers, Nick Holt, & John C. Spence

Abstract

The Youth Physical Activity Promotion (YPAP) model proposes that children's physical activity (PA) is determined by predisposing, enabling, and reinforcing factors. Consistent with the YPAP model, this study tested whether enjoyment and barrier self-efficacy for PA mediate associations between characteristics of the friendship network and the pedometer-measured PA of children, and differences by gender. Participants were grade 5 children involved in the APPLE Schools project (A Project Promoting healthy Living for Everyone in schools) in 2013. Students wore piezo-electric time-stamped pedometers for 9 consecutive days, nominated up to 10 close friends in their school and grade, and completed survey questions on enjoyment of PA, barrier self-efficacy for PA, and social support for PA from friends. Ego-network variables were created from the friendship nominations, including friend PA and in-degree centrality (i.e., social status). Using partial structural equational models we observed friend support for PA, in-degree centrality, and friend PA to be directly associated with PA in males and enjoyment for PA to mediate the associations between friend support and PA, and in-degree centrality and PA. Only friend PA was directly associated with PA in females with no identified mediators. This research provides support for the utility of the peer influence (reinforcing factor) and enjoyment (predisposing factor) components of the YPAP model in the context of children's PA and suggests that friends may be important influence agents on the PA of children in late childhood.

A fundamental concern of health promotion is helping the population become and maintain physical activity (PA) across the lifespan (Cardinal, 2014). The childhood years (5-11 years-old) are a particular critical time as early positive and negative PA experiences "set the tone" for lifestyle choices across the lifespan (Bailey, Cope, & Parnell, 2015). Evidence also suggests that PA patterns are established during childhood and active children tend to become active adults (Craigie, Lake, Kelly, Adamson, & Mathers, 2011). Unfortunately most children around the world to not achieve the recommended guidelines of 60 minutes of moderate-to-vigorous physical activity (MVPA) per day (Tremblay et al., 2016) which is equivalent to 12,000 steps/day (Colley, Janssen, & Tremblay, 2012). For example, among Canadian children, 60% of males and 35% of females meet the PA guidelines (Roberts et al., 2017). It is widely recognized that PA participation is determined by intra-individual (e.g., enjoyment, self-efficacy) and extra-individual factors (i.e., social and physical environment; Spence & Lee, 2003), and that identifying correlates and determinants will help us understand why some are more active than others, with the strongest and most consistent correlates being the most effective targets for interventions (Sallis, Owen, & Fotheringham, 2000).

Interventions grounded in behavioural science theory should be more successful than those that are not (Glanz & Bishop, 2010). Thus, the testing and refinement of theories is paramount to the development of effective interventions. Such theories should have the most explanatory power when they are behaviour-specific (Rhodes & Nigg, 2011). Although there are known age-related differences in PA for young people compared to adults, few theories or models specifically focus on children (Taylor, Baranowski, & Sallis, 1994; Welk, 1999). For instance, compared to adults, the PA of children is sporadic and intermittent (Bailey et al., 1995; Baquet, Stratton, Van Praagh, & Berthoin, 2007), much of their lives are controlled by adults

(Noonan, Boddy, Fairclough, & Knowles, 2016), and they are motivated and influenced by unique factors (Bauman et al., 2012). Specifically, children are motivated to participate in PA to a) develop and demonstrate physical competence, b) develop or affirm social relationships, and c) because it is fun and enjoyable (Stuntz & Weiss, 2010).

The Youth Physical Activity Promotion Model (YPAP; Welk, 1999) takes a broad perspective on the factors that predispose, enable, and reinforce the PA of children and adolescents within a behaviour- and population-specific and testable mediation framework. Enabling factors for PA include fitness, skills, access, and the environment; reinforcing factors include family, peer, and coach influences; and predisposing factors include psychological factors around "am I able?" (i.e., perceptions of competence, self-efficacy) and "is it worth it?" (i.e., enjoyment, beliefs, attitudes). Further, personal demographics such as age, gender, ethnicity/culture, and socioeconomic status may interact with each of the main components of the model.

As children mature and slowly gain independence and autonomy from their parents, friends become important companions and influence agents (Rubin, Bukowski, & Bowker, 2015). For example, with increasing age, children are given more independent mobility within their neighborhood (Janssen, Ferrao, & King, 2016; Riazi & Faulkner, 2018), which gives them more opportunities to socialize and play with friends (Prezza et al., 2001). Though parents remain essential sources of support and influence throughout the school-aged years (Yao & Rhodes, 2015), the importance of friends is likely to gradually increase across the primary school years, though the exact timing of this shift is unclear in regards to PA. This is not surprising considering children are with peers for a large part of the school day including active play at recess, physical education classes, and through organized PA and sports programming (Brustad,

2012). PA is also more enjoyable and fun with others, there is a greater variety of games to play when with others (e.g., two person games, team based activities), and the simple presence of friends increases PA levels (Barkley et al., 2014; Salvy et al., 2008; Sanders et al., 2014).

As children mature and their social worlds expand, they become sensitive to their social status in the peer group, particularly with activities involving prestige and popularity (Bandura, 1989). Further, they judge their valued capabilities by comparing themselves to their friends (Bandura, 1989). Physical ability is known to be a salient marker of social status in many friendship groups (Jago et al., 2009) and is likely a factor that children compare themselves on. In addition, around the middle-to-late childhood years children develop a need for interpersonal intimacy and validation of self-worth that can only be fulfilled by their friends (Sullivan, 1953). These needs along with increased cognitive maturity and the ability to take the perspective of their friends, also leads to closer friendships than were evident in younger years. Thus, although friends are known to be important throughout the lifespan (Bagwell & Schmidt, 2011), the developmental significance of friends changes during the middle-to-late childhood years, of which the latter is a focus of this study.

Research on friendships show that positive messaging around PA (including social support), co-participation in PA with friends, and the PA of friends are associated with PA in children and adolescents (Maturo & Cunningham, 2013). Some research has also shown in-degree centrality to be associated with PA levels in adolescents (Simpkins, Schaefer, Price, & Vest, 2013), particularly for males (de la Haye, Robins, Mohr, & Wilson, 2010). In this study we examine: 1) encouragement and co-participation as indicators of *social support* (i.e., aid and assistance provided through interpersonal interactions; Heaney & Israel, 2008); 2) friend PA, which is often referred to as *modeling* (i.e., friends serving as positive or negative role models;

Bandura, 1986); and, 3) *in-degree centrality* which reflects social status and being well liked (Cillessen & Marks, 2011). A significant gap in the literature, however, is the lack of understanding on *how* friends influence PA (Silva, Lott, Wickrama, Mota, & Welk, 2012; Welk, 1999). As proposed in the YPAP, the predisposing factors of "Am I able?" and "Is it worth it" could explain the psychological processes by which friends influence children's PA. Such information is extremely valuable for theory testing and refinement and for guiding theory-use within the development of friendship-based interventions and programming.

Self-efficacy is one of the most consistent correlates of children's PA (Bauman et al., 2012), and within the child PA context is defined as beliefs in the capacity to be physically active (i.e., task self-efficacy) and to be physically active despite existing barriers (i.e., barriers self-efficacy), although the latter is most commonly assessed (Voskuil & Robbins, 2015). The idea that self-efficacy is a mediator of the association between friendship influence variables (i.e., friend social support and PA) and child PA is consistent with social cognitive theory (SCT) where social persuasion (i.e., defined as social support) and modeling are important sources of self-efficacy (Voskuil & Robbins, 2015). Specifically, social persuasion involves receiving encouraging feedback from others on one's capabilities within realistic bounds, which can lead to improved confidence of one's abilities (i.e., self-efficacy beliefs; Bandura, 1997). People also gain information about their capability by comparing themselves to similar others (particularly on gender and age) and the norms of the group via vicarious observation (i.e., modeling). Considering friends tend to be alike on various characteristics (e.g., age, gender, ethnicity; McPherson, Smith-Lovin, & Cook, 2001), the friendship group is likely an important source of comparison. Thus, by watching their friends perform physical skills (tasks) and overcome barriers (e.g., homework, being tired), a child could increase their confidence in the ability to

perform the same skills and overcome barriers to being physically active (i.e., self-efficacy), and over time their self-efficacy shapes their choices, effort, and persistence of PA participation.

Enjoyment is a well-recognized internally-driven motive for PA participation that is particularly relevant for children (Stuntz & Weiss, 2010). Enjoyment also goes hand in hand with co-participation in PA with friends, as children describe enjoying PA because it is a chance to "hang out with friends" (Jago et al., 2009; Stanley, Boshoff, & Dollman, 2013). Further, children enjoy playing more and are motivated to play longer when in the presence of friend(s) compared to when alone (Sanders et al., 2014). Thus, as identified in the YPAP, enjoyment appears to be an important psychological mechanism by which friends influence PA in children.

Several studies have demonstrated that friend social support for PA is associated children's PA in late childhood (Bergh et al., 2011; Ievers-Landis et al., 2003; Silva et al., 2012). Though some work has demonstrated self-efficacy and enjoyment of PA as mediators of the parent support and child PA association (Wing, Bélanger, & Brunet, 2016), mediators of the friend support and child PA association is limited. However, friend support has been shown to indirectly associate with adolescent PA via enjoyment and self-efficacy (Chen & Dai, 2016; Chen, Sun, & Dai, 2017), yet differences by gender are unknown. Considering friends are significant aspects of children's lives in late childhood, examinations of mediators or "mechanisms of influence" are needed to understand how this influence occurs.

Despite there being several known ways friends influence children's PA (Maturo & Cunningham, 2013; Sawka, McCormack, Nettel-Aguirre, Hawe, & Doyle-Baker, 2013), to our knowledge only social support has been tested within the YPAP model. Thus, examining whether additional friendship variables fit within the YPAP model is an important next step. Using social network methodology, our study extends previous research by examining the

objectively-measured PA of friends and in-degree centrality, variables identified as correlates of children's PA using this dataset (see study 2) and in recent systematic reviews (Maturo & Cunningham, 2013; Sawka et al., 2013), along with perceived friend social support for PA.

In childhood males are known to be more active than females (Bauman et al., 2012), and several studies have found differences between males and females in regards to friendships and PA in children and adolescents (de la Haye et al., 2010; Marks, de la Haye, Barnett, & Allender, 2015; Salway, Sebire, Solomon-Moore, Thompson, & Jago, 2018; Sawka et al., 2014; Sirard et al., 2013). For example, Salway et al. (2018) observed clustering of accelerometer-measured MVPA within friendship groups to be stronger in male compared to female friendship networks of 8- to 9-year-old children. Another study observed the PA of a best friend to be associated with the accelerometer-measured PA of males, and frequency of co-participation in PA with a best friend to be associated with the PA of females (10-11 years old; Jago et al., 2011). The YPAP model also specifies that key components of the model may be moderated by demographic factors such as gender (Welk, 1999). As such, differences by gender are important to examine, yet few studies have explored gender differences within the YPAP model. Such information can assist with the development of intervention strategies, as it will reveal whether gender-specific targeting is required for friendship-based interventions.

The purpose of this study was to examine whether enjoyment of and barrier self-efficacy for PA mediate associations between characteristics of the friendship network and the pedometer-measured PA of children, and differences by gender. Consistent with the YPAP model we hypothesized that enjoyment of and barrier self-efficacy for PA will mediate associations between 1) friend PA and child PA, 2) friend support for PA and child PA, and 3) in-degree centrality and child PA. The examination of gender differences was exploratory.

Methods

Participants

The participants included grade 5 children living in Edmonton and Fort McMurray, Alberta, Canada. Participating schools were involved in a comprehensive school health project called APPLE Schools (A Project Promoting healthy Living for Everyone in schools; www.appleschools.ca). Data for this study are taken from the annual APPLE Schools evaluation in 2013 which included a student survey. Grade 5 students were specifically chosen to be surveyed because at this age, children possess the cognitive and abstract reasoning capabilities to accurately complete self-report surveys (Dollman et al., 2009), and because grade 6 children were busy preparing for their provincial tests. Initially, 42 schools were recruited. However, 9 of these schools opted not to complete the friendship questions. One additional school had too low participation rates/compliance and their observations were not considered. Ultimately, only children with parent consent and who assented to participate were surveyed and included in the analyses. The final sample included 32 schools and 743 participants.

Measures

Friendship variables. Consistent with previous research, a social network survey was administered to the students to gather information on which children were friends with whom. Using an open-ended format the children were asked to write down the first and last name of up to 10 close friends within the same grade level of their school, defined as "other children you hang around with, talk to, and do things with the most" (de la Haye et al., 2010; de la Haye et al., 2011). Though best friends were also reported, to ensure comparability with the social support scale, we used close friends only for this study. For this study, friendships were determined by both incoming and outgoing nominations (i.e., a friendship was identified if a child either nominated a peer or a peer nominated them). *Friend steps/PA* was calculated as the average

steps/hour of the identified friends (i.e., alters) for each child (i.e., ego). *In-degree centrality* was calculated as the number of incoming friendship nominations. Though in-degree centrality is often considered a measure of popularity (Hawe, Webster, & Shiell, 2004), research in developmental psychology has demonstrated that popularity, defined as prestige, power, and visibility among peers, is closely related to network centrality yet are not the same concept (Cillessen & Marks, 2011). Therefore, in-degree centrality is considered here as a measure of social status and being well liked. Children without any outgoing or incoming friendships were not considered (n = 15).

Four questions on friend support for PA were derived from the Patient-centered Assessment and Counseling for Exercise (PACE) questionnaire (Norman, Schmid, Sallis, Calfas, & Patrick, 2005). Students were asked "During a typical week, how often do your friends… a) encourage you to do sports or physical activities?, b) do physical activity or play sports with you?, c) ask you to walk or bike to school or to a friend's house?, and d) tell you that you are doing well in physical activities or sports?" The response options for this scale included "never", "1-2 days", "3-4 days", "5-6 days", and "every day". Norman et al. (2005) observed the internal consistency of a 5-item scale (i.e., includes a teasing from peers question) completed by paper and pencil to be α = .60 and .75 when measured one-week apart, and a 1-week test-retest to be ICC = .68 with students 11-15 years of age. With a 4-item scale, and 3 of 4 of our scale items (i.e., walk to bike to school replaced with frequency child encourages friend to be active) strong test-retest reliability (ICC = .86), good internal consistency (α = .81), strong correlations between parent and child reports (r = .57, $p < .01$), and correlations with self-reported MVPA (r = .22-.29) with grades 6 to 8 students in the US have been reported (Prochaska, Rodgers, & Sallis,

2002). We observed the internal consistency as α = .75 with total-item correlations between .43 and .61 (see Table 4.1).

Enjoyment and self-efficacy. Enjoyment was measured using the Physical Activity Enjoyment Scale (PACES*;* Moore et al., 2009). Participants were asked to "Please fill in how much you agree or disagree with the following statements". Sixteen statements starting with the stem "when I am active…" describe positive and negative emotions around PA (e.g., "I enjoy it", "I feel bored"). Five-point Likert-type response options ranged from (1) "disagree a lot" to (5) "agree a lot". This scale was originally created by Kendzierski and DeCarlo (1991) with adults and was modified to improve comprehension and reduce redundancy for young adolescents (Moore et al., 2009). Good internal consistency and validity has been established with grade eight females (M_{age} = 13.6 years) and grade three children (M_{age} = 7.72 years*;* Moore et al., 2009; Motl et al., 2001). In our study internal consistency was α = 0.88 with item-total correlations between 0.38 to 0.62 (Table 4.1).

Four questions asked about confidence in overcoming barriers to PA (Saunders et al., 1997). Specifically, the children were asked "How confident are you that you could do the following things on your own time *outside of school hours*? a) be physically active no matter how tired you may be, b) be physically active even if you have a lot of homework, c) ask your parent or other adult to play a physical activity or sport with you, and d) be physically active most days of the week". Responses included "Not confident at all", "A little bit confident", "Quite confident", and "Very confident". Using a 17-item scale containing these questions, internal consistency reliability was α = 0.71 (Saunders et al., 1997). In our study, internal consistency was α = 0.88 with item-total correlations between 0.46 to 0.56 (Table 4.1).

Physical activity. Students wore a time-stamped piezo-electric pedometer for 9 consecutive days and completed diaries indicating when the device was taken off and activities participated in each day. The Omron HJ-720ITC (Ontario, Canada) records hourly wear (worn/not worn) and steps, resets every evening, and stores up to 42 days of data. Evidence of criterion validity of this specific model (Peters, Kate, & Abbey, 2013), and similar Omron models (Hart, Brusseau, Kulinna, McClain, & Tudor-Locke, 2011; Nakae, Oshima, & Ishii, 2008), has been demonstrated. For example, with children (M_{age} = 8.7 years-old) strong correlations were observed between pedometer steps/day with this model and accelerometer-measured MVPA (r = .76) and counts/min (r = .79). To account for the child's activities when the device was taken off, and for non-ambulatory activities (e.g., biking) which are not accurately captured by the device (Tudor-Locke, 2016), the step equivalent of these activities were imputed (see Vander Ploeg, Wu, McGavock, & Veugelers, 2012 for a more detailed description). As per recommended practice, the first and last day of wear were not analyzed (Lubans et al., 2015). Valid pedometer data was determined as 2 valid days of data (Craig, Cameron, Griffiths, & Tudor-Locke, 2010). A valid school day included 8 or more valid hours (log-imputed or worn) between 7am and 8pm and a valid non-school day included 7 or more valid hours (log-imputed or worn) between 9am and 8pm, which represented approximately 60% of their waking day (Peters et al., 2013; Vander Ploeg et al., 2012). Additionally, days were removed if >50% of the daily hours were registered as 0's to ensure that days when the children did not wear the pedometer were excluded. To account for the variation in number of valid hours of daily pedometer data across participants, we operationalized PA as steps/hour (i.e., *ego steps/PA;* Laurson, Welk, & Eisenmann, 2015).

Demographics and covariates. Students self-reported their gender. Their weight and height were measured using a calibrated scale (nearest 0.1 kg) and a standiometer (nearest 1.0

mm), respectively. Weight status was calculated using the World Health Organization's (WHO) growth reference body mass index (BMI) age and sex specific *z*-scores which were classified into healthy weight (*z*-score below 1) and overweight/obese (*z*-score greater than or equal to 1; de Onis et al., 2007; World Health Organization, 2007). One parent also reported their highest level of education (response options: no schooling, elementary, secondary, community/technical college, university, and graduate university), household income (response options: less than $25,000, $25,001-$50,000, $50,001-$75,000, $75,001-$100,000, more than $100,000 and don't know/prefer not to answer), and whether they were born in Canada (yes/no).

Analysis

All assumptions were examined including outliers, normality, linearity, and homoscedasticity. Initially, outliers for PA were determined as daily pedometer steps <1,000 (deleted) and >30,000 (truncated; Lubans et al., 2015). Ego steps (n = 5), friend steps (n = 2), and in-degree centrality (n = 3) with *z*-scores > 3.29 or < -3.29 were truncated. Multivariate outliers were identified as studentized deleted residuals > 3 or < -3 for each of the outcome variables and were deleted (ego steps outliers n = 12, enjoyment outliers n = 22, self-efficacy outliers n = 8). Internal consistency ($\alpha \geq .70$ deemed acceptable), item-total correlations ($\geq .40$ deemed acceptable), and alpha if deleted were also examined in SPSS. Descriptive information was calculated including means and standard deviation/variance for continuous variables, and counts and percentages for categorical variables.

Measurement models were run for each latent variable separately to ensure model fit. Also, to ensure equivalence in measurement across gender, each latent variable was tested for measurement invariance. Configural, metric, and scalar invariance, along with equal residuals were tested one by one by setting equality constraints between gender one by one (i.e., factor loadings, intercepts, and residuals) and testing for significant differences between nested models.

The main analysis involved a multiple group multiple mediation partial structural equational model. First, to compare if differences existed across males and females, structural invariance between gender was tested. This involved setting each pathway as equal between gender (except for the covariates), and comparing the change in model fit (i.e., $\Delta\chi^2$) between the constrained and unconstrained models (Kelloway, 2015c). Significant worsening of model fit indicated significant differences in the model by gender. Analyses controlled for clustering within schools, child weight status, and parent education. Due to the large sample and complexities of conducting such an analysis, dependencies between egos who share friendship ties were not accounted for.

Indirect effects were calculated using the product of coefficient method (Cerin & MacKinnon, 2009) and significance was determined via the delta method (Muthen & Muthen, 1998-2012). Tests of mediation involve the estimation of: 1) the association between aspects of the friendship network and the mediators (α path coefficients); 2) the association between the mediators and PA (β coefficient); and, 3) the mediated effect (αβ path coefficient). Further, consistent with recent recommendations, a significant pathway between the friendship variables and PA (i.e., total effect) was not required for mediation to exist (Cerin & MacKinnon, 2009). The indirect effects are the effect of the friendship network on PA through the mediators and can be interpreted as the unstandardized effect of the exposure on the outcome through the mediator. The direct effects are the association between the friendship network and PA with the indirect effect removed.

Due to some non-normality in the data, the maximum likelihood estimator with robust standard errors (MLR estimator) was used in the partial structural equational models. Absolute model fit was determined by a non-significant χ^2 or a χ^2/df value of ≤ 3 (Iacobucci, 2010) along

with Root Mean Square Error of Approximation (RMSEA; acceptable fit ≤ .06), Comparative Fit Index (CFI; acceptable fit ≥ .95), and Standardized Root Mean Square Residual (SRMR; acceptable fit ≤ .08; Hu & Bentler, 1999). Significant worsening of model fit between nested models for the measurement and structural invariance testing was determined by a significant Satorra-Bentler scaled $\Delta\chi^{2\ \text{difference}}$ test (Muthen & Muthen, 2005) and a ΔCFI of > .01 (measurement invariance only; Cheung & Rensvold, 2002). Significance was set at $p < .05$ for all analyses. Both unstandardized (B) and standardized (β) path coefficients are presented. To interpret unstandardized coefficients in steps/hour units, the coefficient is multiplied by 100.

By default MPlus does not consider any cases with data missing on non-latent x-variables ($n = 100$). Therefore the final analytical sample ($N = 743$) consisted of variables with non-missing values on predictors (friend PA, in-degree centrality) and covariates (parent education, child weight status). Of the cases with complete data on x-variables, missing data was minimal for all latent variable indicators (< 1%; i.e., enjoyment, self-efficacy, friend support). Ego steps had missing data on 11% of cases and those with missing data differed from those who were not missing on in-degree centrality, enjoyment of PA, self-efficacy for PA, and the parent being Canadian born, thus providing evidence that the data was at least partially missing at random (MAR). As such it was appropriate to estimate missing values on steps and latent variables using full-information maximum likelihood (FIML), a powerful method which produces unbiased parameter and standard error estimates along with model fit statistics when data is Missing at Random (MAR; Enders & Bandalos, 2001). Analyses were completed in IBM SPSS 24 (IBM Corporation, 2016) and MPlus version 7 (Muthen & Muthen, 1998-2012).

Results

Demographic data (see Table 4.2), indicate 34.8% of the parents had a university education, and 71.6% of families made over $75,000/year. On average males took significantly more steps/hour (M = 851) than females (M = 742; $p < .01$. Males had an average of 4.43 incoming friendships and their friends took 864 steps/hour, with 90% of their friends having step data. Females had an average of 4.72 incoming friendships and their friends took 765 steps/hour, with 87% of their friends having available step data. The latent factor means did not significantly differ between males and females for self-efficacy ($p = .05$) or enjoyment ($p = .11$). However, the friend support latent factor mean was significantly higher in males compared to females ($p = .04$).

Measurement models. A one-factor model for friend social support achieved model fit (χ^2 [2] = 3.09, p = .21, RMSEA = 0.03, CFI = 1.00, SRMR = 0.01). Factor loadings ranged from 0.43 to 0.67 for females and 0.49 to 0.75 for males (see Table 4.3). Full measurement invariance (i.e., equal residuals) was achieved across gender therefore males and females can be directly compared on this variable (see Table 4.4).

Several studies have found a poor fit to a one factor model for the PACES questionnaire, likely due to a methodological artifact of the wording of positively and negatively worded items (Motl et al., 2001). Consistent with previous research a confirmatory factor analysis was run including models with one-factor, two-factors, one-factor with correlations among negatively worded items, and one-factor with correlations among positively worded items. Each of these models produced a positive-definite error that was uncorrectable which may be due to negatively skewed items on this scale and/or the complex design. Instead of using a smaller subset of items, we combined all 16 items into 4 parcels (4 items each) with balanced factor loading

combinations (i.e., strong, moderate, and weak loadings; Kelloway, 2015a). A one-factor model achieved model fit with 4 parcels (χ^2 [2] = 0.90, p = .64; RMSEA = 0.00; CFI = 1.00, SRMR = 0.00). Factor loadings ranging between 0.67 to 0.82 for females and 0.71 to 0.81 for males (Table 4.3). Full measurement invariance (i.e., equal residuals) by gender was achieved (see Table 4.4). Thus, we were able to compare directly across males and females.

A one-factor model for self-efficacy achieved an acceptable model fit (χ^2 [2] = 6.33, p = .04, RMSEA = 0.05, CFI = 0.99, SRMR = 0.02). Factor loadings ranged between 0.43 and 0.66 for females and 0.45 to 0.73 for males (see Table 4.3). Partial scalar invariance was achieved, whereby the difference between models was non-significant when the first indicator was allowed to vary between gender (see Table 4.4). Because at least two intercepts are constrained to be equal across models we can compare differences in latent factor means across gender, yet the observed means are not comparable (Van de Schoot et al, 2012). Also to ensure model fit in the multiple-group structural models the first indicator was allowed to vary in this model.

Main analyses. The multiple-group mediation path analysis for the friendship network variables predicting PA through enjoyment and self-efficacy, controlling for weight status and parent education, had an acceptable fit to the data (χ^2 [214] = 253.14, *p* = .05; RMSEA = 0.02, CFI = 0.99; SRMR = 0.05). When the model was set as equal between males and females there was also an acceptable fit to the data (χ^2 [228] = 263.29, *p* = .05, RMSEA = 0.02, CFI = 0.99, SRMR = 0.05), which was not significantly different from the unconstrained model ($\Delta\ \chi^2$ [11] = 10.03, *ns*). Despite the non-significant change in model fit we report the results for males and females separately because there are notable differences between males and females in regards to significance of specific path coefficients and indirect effects. However, the equivalence between models suggests that, overall, the model is similar between males and females.

The results for females are presented in Figure 4.1. Friend support for PA was associated with enjoyment of PA (B = 0.17 ± 0.03, $p < .01$) and barriers self-efficacy for PA (B = 0.38 ± 0.05, $p < .01$). Only friend steps was directly associated with ego steps (B = 0.51 ± 0.09, $p < .01$). Consequently, no indirect effects were observed for females (see Table 4.5).

The results for males are presented in Figure 4.2. Friend support for PA was associated with enjoyment of PA (B = 0.16 ± 0.02, $p < .01$) and barriers self-efficacy (B = 0.35 ± 0.04, $p < .01$). In-degree centrality was also associated with both enjoyment of PA (B = 0.02 ± 0.01) and barriers self-efficacy for PA (B = 0.03 ± 0.01, $p = .01$). Enjoyment of PA (B = 1.69 ± 0.56, $p < .01$), friend support for PA (B = 0.66 ± 0.27, $p = .02$), in-degree centrality (B = 0.15 ± 0.06, $p = .01$), and friend steps (B = 0.39 ± 0.09, $p < .01$) were all associated with ego steps. Enjoyment of PA was also found to significantly mediate the association between friend support for PA and ego steps (B = 0.28 ± 0.09, $p < .01$), and the association between in-degree centrality and ego steps (B = 0.03 ± 0.02, $p < .05$; see Table 4.5). Thus, for every 1 unit increase in friend support, enjoyment of PA accounted for **28** steps/hour in ego steps, and for every additional incoming friendship nomination (i.e., in-degree centrality), enjoyment of PA accounted for a **3** step/hour in ego steps. Because self-efficacy was not a significant mediator we did not test for differences in the size of indirect effects between enjoyment and self-efficacy.

Discussion

Informed by the YPAP, we examined whether enjoyment and barrier self-efficacy for PA mediated associations between friendship network characteristics and children's PA along with differences by gender. Though characteristics of friendship networks are known to be associated with PA in children (Maturo & Cunningham, 2013; Sawka et al., 2013), an understanding of mechanisms for how friendship influence occurs is a current limitation of the literature (Silva et

al., 2012; Welk, 1999). We found friend support for PA, in-degree centrality, and friend PA to be directly associated with PA in males, and enjoyment to mediate the associations between friend support and ego PA and in-degree centrality and ego PA. For females, only friend PA was directly associated with PA with no identified mediators. To our knowledge, we are one of the first to confirm mediators of the "peer influence" component of the YPAP model, as measured by perceived social support and social network variables, and objectively-measured PA in children. Our study suggests that friends are important influence agents on the PA of children in the late childhood years, a time when they are beginning to gain autonomy from parents and are concerned about social status (Bandura, 1989).

The indirect effects of enjoyment on the association between friend support for PA and ego PA for males suggests that the co-activity with friends and encouragement from friends may foster enjoyment for PA, which in turn leads to higher PA levels. Specifically, for every 1 unit increase in friend support for PA, enjoyment of PA accounted for 28 steps/hour in males, which amounts to 64-364 steps/day. This is consistent with self-determination theory whereby need-supportive interactions with others is thought to increase intrinsic motivation (i.e., doing an activity out of interest and enjoyment) which leads to behavioural persistence over time (Deci & Ryan, 2008). It is also consistent with qualitative research where 10- to 11-year-old children described maintaining PA participation over time because they enjoy spending time with friends (Jago et al., 2009), and a "draw, write, show, and tell" whereby 10-11 year old children identified co-participation in PA with friends and the presence of friends as key enabling factors and enjoyment as a predisposing factor in their PA engagements (Noonan et al., 2016). Further, in a study of Chinese participants in grades 9-12 enjoyment was a mediator of the association between peer support and self-reported PA (Chen et al., 2017). To the contrary, a study of 10-17

year-olds in the US did not find enjoyment was a mediator of the association between friend support for PA and accelerometer-measured MVPA (Heitzler et al., 2010). These previous two studies were with older samples, however, and did not examine gender differences. A potential reason for our finding of a gender difference in the mediation of enjoyment, which is specifically due to the non-significant association between enjoyment and PA in females, is that some females experience peer victimization in PA settings (Vu, Murrie, Gonzalez, & Jobe, 2006) which could reduce their enjoyment even when they receive support from their friends. It is also "uncool" to be athletic in some female friendship groups (Jago et al., 2009) and thus co-participation in PA with friends would not be enjoyable or reinforce PA in these groups. However, enjoyment of PA was associated with friend support for PA in females, suggesting it is still a relevant psychological variable for the friendship context.

Our results also suggest that higher enjoyment of PA partially accounts for why males with higher social status (i.e., higher in-degree centrality) tend to be more active. Though the effects seem quite low, with enjoyment of PA accounting for 3 steps/hour for every additional incoming friendship nomination, when we consider males with no friends vs. those with 10 friends, enjoyment accounts for a 240-390 steps/day difference between these two groups. This is consistent with qualitative research which observed social status in male friendship groups to be closely linked to athletic ability (Jago et al., 2009). It is also possible that having many peers desire to be their friend gives these children more opportunities to play with different peers and participate in different physical activities in different contexts, which is enjoyable. Indeed, Jago et al. (2009) also observed that children like to be connected to different groups of friends, as they do different activities with different groups of friends and this keeps things interesting.

The lack of indirect effects observed for self-efficacy are surprising considering "modeling" (friend PA) and "social persuasion" (encouragement/praise component of friend support), in particular, are both sources of self-efficacy (Bandura, 1997). There are several potential explanations for the lack of indirect effects observed, which was due to the lack of association between self-efficacy and children's pedometer steps. Because higher intensity activity and organized activities are more difficult to perform than light intensity activity, and thus require more barriers to overcome for participation, it is possible that different results would have been found with other forms of PA. Alternatively, it is possible that barrier self-efficacy for PA is less relevant in this age-group for children's PA, and that task self-efficacy for PA, or the belief in the capacity to be physically active, may be more relevant. Competence could also be important as it was identified by children in a "draw, write, show, and tell" activity as a predisposing factor for their PA (Noonan et al., 2016). Nonetheless, barriers self-efficacy for PA was still positively associated with friend support for PA in both males and females, suggesting that this construct is still relevant in the friendship context.

The direct effects observed between the friendship and PA after accounting for enjoyment and self-efficacy is consistent with the YPAP model. They are also consistent with cross-sectional studies of children and adolescents which observed direct associations between friend social support and self-reported PA (Silva, Lott, Mota, & Welk, 2014; Silva et al., 2012) and accelerometer-measured PA (Heitzler et al., 2010), and friend and ego accelerometer-measured MVPA (Garcia, Sirard, Deutsch, & Weltman, 2016), after accounting for psychological mechanisms. A few studies of adolescents in China however did not find a direct association which may be due to cultural differences (Chen & Dai, 2016; Chen et al., 2017). However, few have examined gender differences. Though our model was not significantly

different between males and females, several differences existed in terms of significance of associations and indirect effects. Specifically, in males, support from friends, friend PA, and in-degree centrality were all associated with PA, whereas in females only friend PA was associated. Thus, in general, the friendship networks of males appear to reinforce and discourage their PA in more diversity of ways than for females.

Despite our study being cross-sectional, which limits the ability to make claims about causality, our findings suggest that friends are important influence agents on the PA of children in late childhood. As such, the healthy promotion of PA at this age does not simply come from adults, and friends may also play a role in shaping PA levels. An understanding of the influence of friends is important because behavioural patterns are established in the younger years and track into adulthood (Craigie et al., 2011), and if the messaging and support from friends clashes with health promotion messages this could negate effects from community and school programs, or positive efforts made by parents. Schools and parents should be made aware of the potential influence of friends so they can help foster healthy role modeling and social support for PA (particularly for males) among friends.

Our study has several strengths. PA was objectively measured for all participants (ego PA) and all friends (friend PA), which is a more accurate measure of ambulatory PA than self- or parental-proxy report measures which can be prone to bias. We also imputed non-ambulatory and non-wear activities recorded in the children's diaries which allowed us to better capture the PA patterns of the children (Vander Ploeg et al., 2012). The use of latent variables and structural equational modeling allowed us to gain an overall measure of model fit as well as specific parameter estimates; model complex path models with multiple mediators, outcomes, and groups; simultaneously examine the measurement and structural models; and more accurately

estimate parameters by modeling “pure” latent variables less contaminated by measurement error (Kelloway, 2015b). The significance of the mediated effect was also tested using the product of coefficient method which is superior to traditional approaches (Cerin & MacKinnon, 2009). We also had a fairly large sample of children which provided sufficient power to test a complex model and differences by gender. The sample also includes families from a wide range of socioeconomic backgrounds, which are generally hard to reach. A final strength is the use of the YPAP, an inherently simple behaviour- and population-specific and testable mediation framework, to guide our study. Use of theory is particularly important for guiding mediation research that is cross-sectional (MacKinnon, 2008), and the testing and refining of theories is critical for advancing topic areas and interventions within the literature (Baranowski, Anderson, & Carmack, 1998).

The main limitation is the cross-sectional design which does not allow us to make any firm conclusions around causality. The schools were also participating in a health promotion program called APPLE Schools which may reduce the generalizability of the findings to schools without comprehensive school health programming. In addition, it is possible that the short list of items included in the self-efficacy instrument may have contributed to the null associations with PA. Although studies often use a few items from larger scales (e.g., Silva et al., 2014; Silva et al., 2012; Verloigne et al., 2014) longer measures that capture more of the barriers faced by children (e.g., parental restriction, weather, access to screen devices; Saunders et al., 1997) and includes barriers related to friendship interactions (e.g., confidence in finding a friend to play with) may more accurately measure this construct in this context and is worthwhile investigating further. Finally, due to the social network methodology used for collecting friendship nominations (i.e., bounded networks of within grade and schools), friend PA and in-degree centrality only pertain to school-

based friendships. Children do report having strong friendships with peers at school who they also spend time with at and outside of school (Jago et al., 2009), and thus our methods likely captured a great of children's friendships. However children also have friends from their neighborhood and organized activities (Jago et al., 2009), and the potential influence of these friends were not captured in our friend PA and in-degree centrality variables (but was captured in the friend social support variable).

It would be worthwhile to also examine mediators at the dyad-level using social network analysis techniques such as Quadratic Assignment Procedure (QAP) or Exponential Random Graph Modeling (ERGM). This approach would take into account the enjoyment and self-efficacy of both the ego and each of their friends and thus would be a more precise measure of mediation effects. Further studies would also benefit from examining mediators at different age-groups to uncover whether different process are at play at different developmental stages. Longitudinal research is also needed to establish temporal precedence and provide greater evidence of causality.

In summary this study applied components of the YPAP to examine whether enjoyment and barrier self-efficacy for PA mediate associations between characteristics of the friendship network and the pedometer-measured PA of grade 5 children. For males, friend support, friend PA, and in-degree centrality were directly associated with the children's PA and enjoyment mediated the associations between friend support for PA and child PA and network centrality and child PA. For females, only friend PA was directly associated with ego PA, and no significant mediators were found. This research provides support for the utility of the peer influence (reinforcing factor) and enjoyment (Is it worth it? predisposing factor) components of the YPAP model in the context of children's PA.

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Table 4.1

Internal consistency for the latent variables

	Chronbach's alpha	Item-Total Correlation	Alpha if deleted
Friend Support	.75		
Encouragement		.61	.66
Co-participation		.59	.68
Active transportation		.43	.76
Praise		.59	.67
Self-efficacy	.69		
Active regardless of tiredness		.56	.58
Active even if have homework		.46	.64
Ask adult to be active		.37	.70
Active most days of the week		.55	.59
PA enjoyment	.88		
Enjoy it		.62	.87
Feel bored		.52	.87
Dislike it		.48	.87
Find it pleasurable		.58	.87
No fun at all		.43	.87
Gives me energy		.43	.87
Makes me depressed		.38	.87
Very pleasant		.61	.87
Body feels good		.59	.87
Get something out of it		.44	.87
Very exciting		.61	.87
Frustrates me		.46	.87
Not at all interesting		.47	.87
Strong feeling of success		.58	.87
Feels good		.60	.87
Rather be doing something else		.55	.87

Table 4.2

Descriptive information for grade 5 children participating in the APPLE Schools project in 2013

	n	Males	Females	Total
Ego total steps/hour – mean (SD)	662	851 (270)	742 (224)	793 (252)**
Friend steps/hour – mean (SD)	743	864 (169)	765 (132)	812 (159)**
No. of incoming friends – mean (SD)	743	4.43 (2.66)	4.72 (2.48)	4.58 (2.57)
Same gender friends – count (%)				
All same gender	743	204 (57.3%)	226 (58.4%)	430 (57.9%)
≥ 1 opposite gender		152 (42.7%)	161 (41.6%)	313 (42.1%)
Parent education – count (%)	743			
Elementary or less		4 (1.1%)	4 (1.0%)	8 (1.0%)
Secondary		93 (26.1%)	92 (23.8%)	185 (24.9%)
College		139 (39.0%)	153 (39.5%)	292 (39.3%)
University		74 (20.8%)	72 (18.6%)	146 (19.7%)
Graduate university		46 (12.9%)	66 (17.1%)	112 (15.1%)
Household income – count (%)	479			
<$25,000		13 (3.7%)	14 (5.9%)	27 (5.6%)
$25,000-$50,000		27 (11.2%)	29 (12.2%)	56 (11.7%)
$50,001-$75,000		22 (9.1%)	31 (13.0%)	53 (11.1%)
$75,001-$100,000		32 (13.3%)	26 (6.7%)	58 (12.1%)
>$100,000		147 (61.0%)	138 (35.7%)	285 (59.5%)
Parent born in Canada – count (%)	740			
No		78 (22.1%)	137 (35.4%)	215 (29.1%)
Yes		275 (77.9%)	250 (64.6%)	525 (70.9%)

Note. Ego steps, friend steps, and number of incoming friendships were compared between males and females using an independent samples *t*-tests; **$p < .01$.

Table 4.3

Factor loadings for latent variables

	Females				Males			
	Mean	Variance	Standardized Factor Loading	Error Variance	Mean	Variance	Standardized Factor Loading	Error Variance
Friend support								
Encouragement	1.57	1.65	0.68	0.54	1.76	1.83	0.75	0.45
Co-participation	2.00	1.56	0.65	0.58	2.20	1.65	0.75	0.44
Active transportation	1.26	1.66	0.43	0.81	1.34	1.81	0.49	0.76
Praise	1.74	1.74	0.68	0.54	1.90	1.84	0.74	0.45
Self-efficacy								
Active regardless of tiredness	2.88	0.63	0.66	0.56	3.02	0.68	0.73	0.47
Active even if have homework	2.78	0.82	0.54	0.71	2.74	1.01	0.54	0.70
Ask adult to be active	3.09	0.89	0.43	0.82	3.07	0.95	0.45	0.80
Active most days of the week	3.45	0.56	0.65	0.58	3.39	0.55	0.71	0.50
Enjoyment								
Parcel 1	4.55	0.31	0.69	0.52	4.51	0.28	0.71	0.50
Parcel 2	4.60	0.23	0.67	0.56	4.53	0.25	0.71	0.50
Parcel 3	4.46	0.27	0.82	0.33	4.42	0.34	0.77	0.40
Parcel 4	4.52	0.33	0.75	0.44	4.46	0.34	0.81	0.35

Table 4.4

Measurement invariance across gender for the latent variables

	χ^2 (df)	$\Delta\chi^2$	CFI	ΔCFI
Friend support				
Configural invariance	6.23 (4), $p = .18$		1.00	
Metric invariance	12.52 (8), $p = .13$	6.22 (4), *ns*	0.99	0.01
Scalar invariance	17.52 (12), $p = .13$	5.80 (4), *ns*	0.99	0.00
Equal residuals	21.78 (16), $p = .15$	4.38 (4), *ns*	0.99	0.00
Self-efficacy				
Configural invariance	6.93 (4), $p = .14$		0.99	
Metric invariance	9.47 (8), $p = .30$	2.87 (4), *ns*	1.00	0.01
Scalar invariance	24.60 (12), $p = .02$	18.14 (4), $p < .01$	0.97	0.03
Free intercept of item 1	12.55 (11), $p = .32$	2.85 (3), *ns*	1.00	0.00
Enjoyment				
Configural invariance	2.21 (4), $p = .70$		1.00	
Metric invariance	10.68 (8), $p = .22$	11.64 (4), $p < .03$	1.00	0.00
Scalar invariance	15.67 (12), $p = .21$	4.98 (4), *ns*	1.00	0.00
Equal residuals	25.33 (16), $p = .06$	8.55 (4), *ns*	0.99	0.01

Note. Models required $\Delta\chi^2$ significant at $p < .05$ and CFI change > 0.01.

Table 4.5

Indirect effects of the association between friendship characteristics and physical activity in grade 5 children participating in the APPLE Schools program in 2013

	Females			Males		
	B (SE)	*p*-value	β (SE)	B (SE)	*p*-value	β (SE)
Friend PA → ego PA						
Total effects	0.50 (0.09)	<.001	0.30 (0.05)	0.40 (0.10)	<.001	0.25 (0.06)
Total Indirect effects	-0.01 (0.03)	0.84	0.00 (0.02)	0.01 (0.02)	.44	0.01 (0.01)
Specific indirect effects						
Enjoyment indirect effects	-0.01 (0.02)	0.80	0.00 (0.01)	0.00 (0.02)	.84	0.00 (0.01)
Self-efficacy indirect effects	0.00 (0.01)	0.96	0.00 (0.00)	0.01 (0.02)	.61	0.01 (0.01)
Direct effects	0.51 (0.09)	<.001	0.30 (0.05)	0.39 (0.09)	<.001	0.25 (0.06)
Friend support → ego PA						
Total effects	0.38 (0.18)	.03	0.15 (0.06)	0.66 (0.17)	<.001	0.25 (0.06)
Total indirect effects	0.14 (0.18)	.44	0.05 (0.07)	0.01 (0.17)	.96	0.00 (0.06)
Specific indirect effects						
Enjoyment indirect effects	0.04 (0.17)	.79	0.02 (0.06)	0.28 (0.09)	<.01	0.10 (0.04)
Self-efficacy indirect effects	0.09 (0.31)	.76	0.04 (0.12)	-0.27 (0.19)	.16	-0.10 (0.07)
Direct effects	0.24 (0.27)	.38	0.09 (0.11)	0.66 (0.27)	.02	0.25 (0.10)

No. incoming friends → ego PA						
Total effects	0.08 (0.05)	.12	0.09 (0.06)	0.16 (0.06)	.01	0.16 (0.06)
Total indirect effects	0.01 (0.01)	.39	0.01 (0.01)	0.01 (0.02)	.46	0.01 (0.02)
Specific indirect effects						
Enjoyment indirect effects	0.00 (0.01)	.80	0.00 (0.01)	0.03 (0.02)	<.05	0.03 (0.02)
Self-efficacy indirect effects	0.00 (0.01)	.77	0.00 (0.02)	-0.02 (0.02)	.28	-0.02 (0.02)
Direct effects	0.07 (0.05)	.16	0.08 (0.06)	0.15 (0.06)	.01	0.15 (0.06)

Note. β = standardized path coefficients; B = unstandardized path coefficients; PA = physical activity; to interpret the unstandardized path coefficients in steps/hour the presented values must be multiplied by 100.

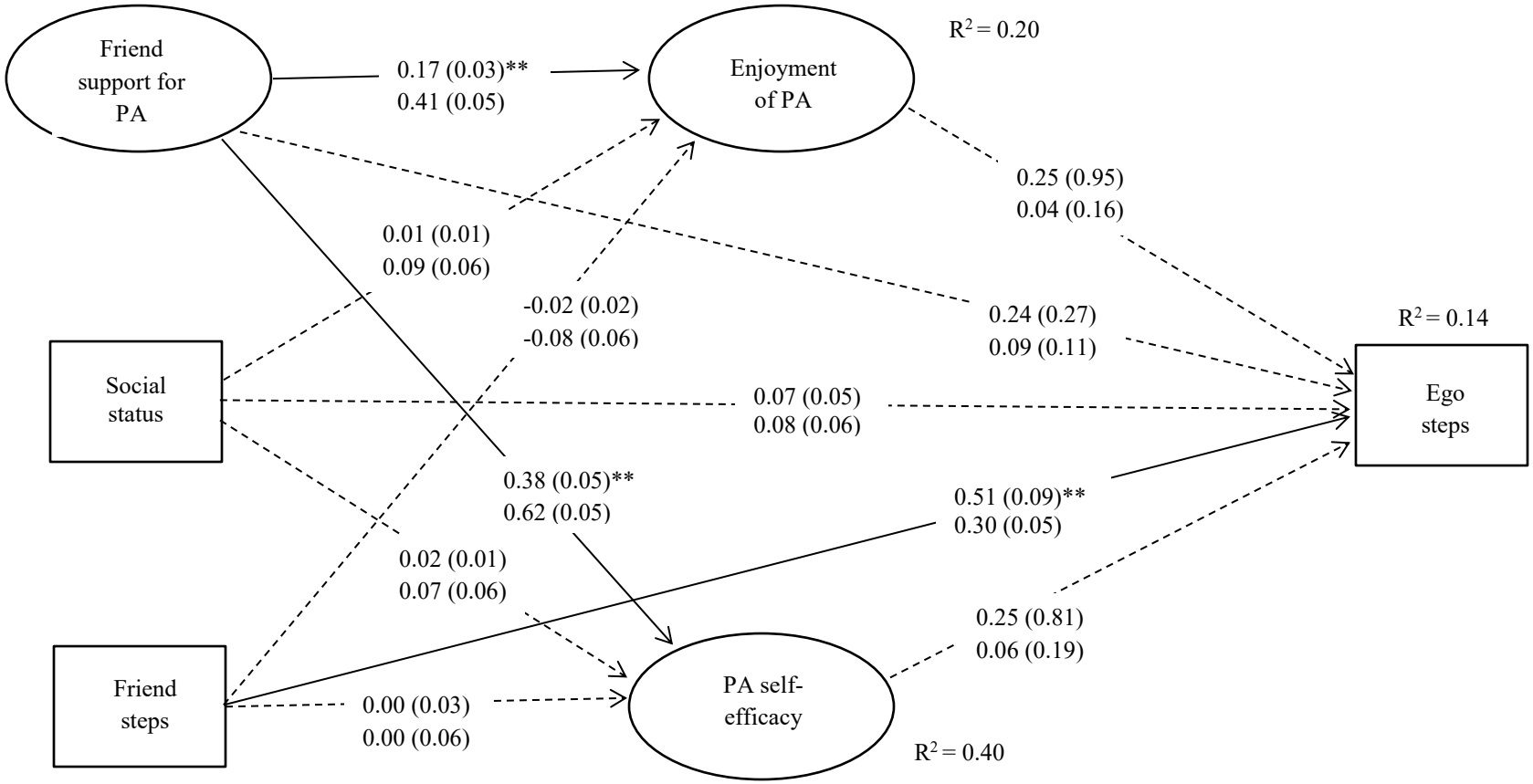

Figure 4.1. Multiple-group multiple mediator structural equational model which examined whether enjoyment and self-efficacy for physical activity mediate the association between characteristics of the friendship network and ego physical activity (PA) in *females*. Unstandardized path coefficients (B [SE]) are presented on *top* and standardized path coefficients are (β [SE]) are presented on the *bottom*; **$p < .01$; *p*-values are based on unstandardized estimates; model fit was χ^2 (214) = 253.14, $p = .05$; RMSEA = 0.02, CFI = 0.99; SRMR = 0.05; variables in circles indicate latent variables and squares indicate observed variables; dotted lines are non-significant pathways and solid lines are significant pathways; to interpret the unstandardized path coefficients in steps/hour the presented values must be multiplied by 100.

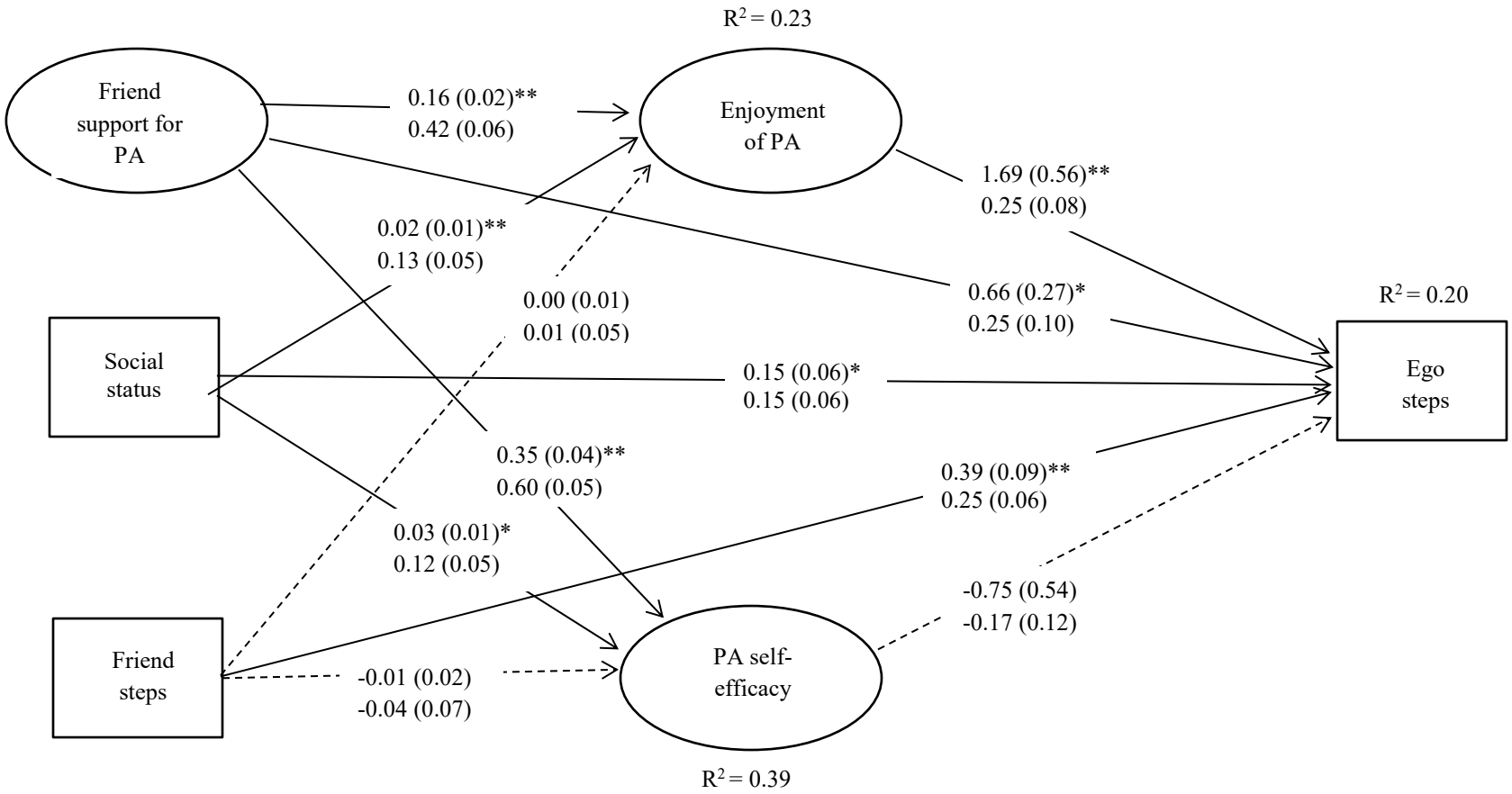

Figure 4.2. Multiple-group multiple mediator structural equational model which examined whether enjoyment and self-efficacy for physical activity mediate the association between characteristics of the friendship network and ego physical activity (PA) in *males*. Unstandardized path coefficients (B [SE]) are presented on *top* and standardized path coefficients are (β [SE]) are presented on the *bottom*; **p* < .05; ***p* < .01; *p*-values are based on unstandardized estimates; model fit was χ^2 (214) = 253.14, *p* = .05; RMSEA = 0.02, CFI = 0.99; SRMR = 0.05; variables in circles indicate latent variables and squares indicate observed variables; dotted lines are non-significant pathways and solid lines are significant pathways; to interpret the unstandardized path coefficients in steps/hour the presented values must be multiplied by 100.

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Chapter 5: GENERAL DISCUSSION

The purpose of this dissertation was to examine the role of friendship networks in the physical activity (PA) and screen time (ST) of grade 5 children. The topic of friendships is important at this age (i.e., 10-11 years-old) as friends are thought to increase in importance during the middle-to-late childhood years (Sullivan, 1953). My findings, along with the existing literature (Sawka, McCormack, Nettel-Aguirre, Hawe, & Doyle-Baker, 2013) suggest that characteristics of the friendship network are associated with the PA and ST of children and, thus, friends may also be influence agents for these health behaviours. Several gaps in the friendship network, PA, and ST literature were addressed including: 1) a lack of studies in the late childhood years (**all studies**); 2) the consideration of a diverse range of possible friendship network influences including social support and social network variables (**studies 2-3**); 3) the comparison of during vs. outside of school periods (study 1); 4) the test of psychological mechanisms (**study 3**); 5) a specific focus on network position including children central and isolated in the network (**study 2**); and 6) an examination of friendship networks and ST (**study 2**). A working theoretical framework specific to friendship networks and children's PA and ST was also proposed. As such, my research helps to progress this important topic area.

Study 1 included a whole-network dyadic-level analysis of 27 schools and 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 across gender, strength of friendship (close vs. best friends), and during vs. outside of school PA. Overall, similarity in total PA between female friends was observed. However, when close friends and best friends were examined separately, female best friends exhibited similar PA on school days and female close friends on non-school days. Though initial analyses of directional friendships indicated no

similarity in PA for males, a post-hoc analysis revealed that best reciprocated friends were similar on total PA. Because this was a cross-sectional study, the similarity of PA among friends could be due to selection or influence, and influence could occur because of several *interpersonal processes* including modeling, co-participation, and encouragement from active friends. The dyadic-level approach and MR-QAP analysis were a strength of this study as it helped control for similarity due to confounding effects (e.g., shared environment, availability factors), and retained more information than ego-network approaches.

Studies 2 and 3 employed an ego-network analysis which allowed us to retain more schools (n = 33), incorporate several friendship network variables (i.e., social network characteristics, perceived social support), test multiple mediators using appropriate statistics (i.e., Sobel test), and employ partial structural equational models. Specifically, study 2 built on study 1 and investigated whether characteristics of the friendship network are associated with the pedometer-measured PA and self-reported ST of children, and differences by gender. For females, friend PA was associated with their PA, and friend screen co-participation, friend ST (when paired with daily discouragement of sedentary activities), and in-isolate status were associated with their ST. Whereas for males, friend PA, friend support for PA, in-degree centrality, and in- and out-isolate status was associated with their PA, and friend discouragement of sedentary activities and screen co-participation were associated with their ST. Thus, this study demonstrated several ways that friendship networks may influence the PA and ST of children, as well as the importance of considering network position.

Study 3 built on study 2 by testing *psychological mechanisms* by which friendship networks may influence PA as informed by the Youth Physical Activity Promotion (YPAP) model (Welk, 1999). This study tested whether enjoyment and barrier self-efficacy for PA

mediate associations between characteristics of the friendship network and the pedometer-measure PA of children, and differences by gender. Friend support was associated with enjoyment and self-efficacy for PA in males and females. However, for males, enjoyment of PA was a mediator for the associations between friend support and child PA, and in-degree centrality and child PA. No mediators were observed for females. These findings provide support for the "peer influence" and "predisposing" components of the YPAP model.

Theoretical Contributions/Implications

This body of research supports two core tenants of social network theory (SNT), including people are shaped by and take action in response to their network environment (studies 1-3), and a person's position in their network impacts their behaviour (studies 2-3). Along with SNT I have drawn upon and several health behaviour theories (i.e., YPAP, social cognitive theory, self-determination theory, social support theory, social norms theory), to develop a working model of how friendship networks influence the PA and ST of children (see Figure 1.2; Stearns & Spence, 2017). This model is important because, although SNT is beneficial for understanding how networks tend to operate, it does not describe the interpersonal processes (i.e., *function*) and psychological mechanisms of how social networks influence PA and ST. As such, it builds upon existing theory and integrates contemporary concepts to potentially guide future research. It is also consistent with the YPAP model (Welk, 1999), yet adds more specificity and greater depth of knowledge in the "peer influence" component. Support for several *interpersonal processes* were observed including friend social support for PA (i.e., encouragement, co-participation, males only) and ST (i.e., discouragement of sedentary activities, co-participation, both males and females), friend modeling of PA (i.e., friend PA, both males and females), social status for PA (i.e., in-degree centrality; males), and

opportunities/barriers for PA and ST (i.e., in-isolate status; males; out-isolate status, females). In addition, support was found for the enjoyment and self-efficacy for PA predisposing factors as important psychological constructs in the child friendship network and PA context, yet only enjoyment acted as a mediator.

One component of the working model that deviates from other models is the explicit recognition that bidirectional associations likely occur between friendship factors and child behaviour. This is consistent with reciprocal determinism of behaviour, cognition, and environment described in social cognitive theory (Bandura, 1989). This bidirectionality is particularly relevant to friendship networks as friendships are typically equalitarian and reciprocal. As such, children likely select friends who are similarly active and sedentary and are influenced by their friends over time. Children also likely seek out friends who will support their current PA and ST habits, and this support over time will influence their behaviour. Further, males who have greater physical ability and are more physically active are likely to be desired and thus chosen by many to be a friend (i.e., in-degree centrality), and over time having many children desire to be their friend could provide more opportunities for PA and increase their status. Finally, children who are isolated have less opportunities for playing with peers, and thus are less physically active and more sedentary, and over time their low PA and high screen time habits could limit their ability to make friends.

My research also demonstrates the value of SNT and social network analysis (SNA) for studying relationships and networks in the health behaviour literature. The social network paradigm has been employed in various contexts such as relationships among active living organizations and policy use (Loitz, Stearns, Fraser, Storey, & Spence, 2017), obesity prevention networks among child care staff (Marks, Barnett, Foulkes, Hawe, & Allender, 2013), advice and

discussion networks among parents in a childhood obesity prevention program (Gesell, Barkin, & Valente, 2013), and professional connections among junior scholars (Godley, Glenn, Sharma, & Spence, 2014). This approach can also be adopted in all phases of program development (Valente, Palinkas, Czaja, Chu, & Brown, 2015). According to Valente (2015), a social network perspective can be implemented in any discipline to address any health topic and thus should be considered and utilized more frequently with researchers in the health behaviour field.

Methodological Implications

My research also highlights how different definitions and calculations of friendship networks can impact findings. Study 1 observed different results when friendship ties were directional vs. only reciprocated. Though it is common to use only reciprocated friendships in developmental psychology (Rubin, Bukowski, & Bowker, 2015), no standard practice exists in the health behaviour literature and reciprocated nominations are not typically used (Sawka et al., 2013). At a minimum, studies need to report how friendship network variables were calculated as friendships can be defined as incoming ties, outgoing ties, reciprocated ties (min symmetrized data), all ties (max symmetrized data), or for dyadic-level data, friendship matrices can be kept as directional (as was done in study 1). With the availability of more advanced statistical analysis techniques (e.g., Exponential Random Graph Modeling [ERGM], Stochastic Actor Based Modeling [ABM]), directional data is now more commonly used because it retains more information. The PA and ST field would benefit from collectively deciding on the most appropriate definition of friendship ties to allow for greater consistency and thus comparability across studies.

Additionally, the discrepancy in findings between study 1 and 2 in regards to whether the PA level of friends is associated with PA of males demonstrates how methodological decisions

made with social network data can impact findings. Several differences exist between the two studies which could help explain the discrepancy, including: 1) the calculation of friendship (i.e., study 1: directional ties, study 2: max symmetrized ties); 2) different samples (study 1: all participants with valid pedometer data from 27 schools, study 2: participants with valid data on covariates and friendship network variables from 33 schools); 3) use of cross- vs. same-gender friendships (study 1: only same-gender friendships, study 2: both same- and opposite-gender friendships); and, 4) the level of analysis (study 1: dyadic-level, study 2: individual-level). When possible, dyadic-level analysis tends to be preferred as it appropriately deals with the dependency inherent in network data, and helps account for similarity in behaviour due to confounding factors such as shared friendship environments and opportunity (i.e., who is available to choose as a friend; McPherson, Smith-Lovin, & Cook, 2001; Zhang, de la Haye, Ji, & An, in press). Yet these types of analyses can be quite complex to do and in my experience are difficult for practitioners to understand. As well, the differences observed between males and females across the three studies highlights the importance of considering males and females separately.

Strengths

The strengths of the three studies have been discussed in the previous chapters and are briefly summarized here. First, the use of data collected via sociometric surveys allowed us to gather information on both incoming and outgoing friendships and to objectively measure the PA of children's friends. Second, the relatively large sample size ensured we were sufficiently powered to complete partial structural equational models, test interactions, and compare males and females. Third, we focused on the late childhood years, a time when friends become more prominent in children's lives (Sullivan, 1953), yet an age-group which has received less attention in the literature than adolescents (Sawka et al., 2013). Fourth, we objectively measured PA using

pedometers which is a more precise measure of total ambulatory activity than self-report, and we imputed steps for non-ambulatory (e.g., biking) and non-wear activities to ensure all types of physical activities were captured. Fifth, the use of advanced statistical approaches allowed us to complete a dyad-level analysis (MR-QAP; study 1), use latent variables when possible, and to examine several outcomes and mediators simultaneously (path analysis/structural equational modeling; studies 2 and 3). Sixth, the inclusion of both perceived and social network friendship variables allowed us to investigate a myriad of possible friendship influences and to determine which are the most important. Seventh, our mediation analysis in study 3 was a first step in addressing *why* friends may influence the PA of children, a current limitation of the literature (Silva, Lott, Wickrama, Mota, & Welk, 2012; Welk, 1999). Eighth, we are the first to examine similarity of objectively-measured PA among friends for during vs. outside of school periods which provided insights into when friends may be most influential (i.e., for females, best friends on school days and close friends on non-school days). Ninth, the examination of isolates is an understudied topic and our findings underscore the importance of focusing on these at-risk children. A final strength of this dissertation is the use of theory to guide decisions about research questions, data collection, and analysis.

Theory is important because it provides a comprehensive and parsimonious ordering scheme for behavioural correlates, along with mechanisms of influence, and knowledge on how to achieve behaviour change (Glanz, Rimer, & Viswanath, 2015; Rhodes & Nigg, 2011). Though testing entire theories is important (Rhodes & Nigg, 2011), with the social network perspective taken in my dissertation, I considered it necessary to integrate SNT with several health behaviour theories. Also, because friendship networks may influence children's PA and ST via several interpersonal processes (Berkman, Glass, Brissette, & Seeman, 2000; Berkman & Krishna,

2014), I took a comprehensive approach to addressing how several theories and concepts may explain this influence, which are consistent with interpersonal processes already proposed in the friendship literature (Salvy, De La Haye, Bowker, & Hermans, 2012).

Limitations

The limitations of each study have been discussed in previous chapters and are briefly summarized here. First, the cross-sectional design limits our ability to draw conclusions around causality. In contrast to relationships with adults which typically involve a power hierarchy, relationships among friends are more egalitarian and reciprocal (Rubin & Bowker, 2018) and, thus, influence is likely bidirectional. However, support exists in the literature for a larger "influence" than "selection" effect for PA in children (Gesell, Tesdahl, & Ruchman, 2012) and adolescents (de la Haye, Robins, Mohr, & Wilson, 2011). Second, the participants in all studies were currently participating in a comprehensive school-based program called APPLE Schools. Though, many schools have health promotion initiatives and comprehensive school health is a part of the existing Alberta curriculum, considering APPLE Schools was effective at improving PA levels (Fung et al., 2012; Vander Ploeg, McGavock, Maximova, & Veugelers, 2014), our findings may not generalize to schools without health promotion initiatives. However, many children in these schools are still not meeting PA guidelines, and children still report low levels of support for PA from friends, suggesting that incorporating friendship network components within existing health promotion programming could benefit these schools and others. Third, the schools were conveniently sampled to participate in the APPLE Schools program, and different recruitment strategies were used in different waves of recruitment (e.g., schools in lower socioeconomic status neighborhoods were recruited in Edmonton, and all schools in Fort McMurray were recruited). Though they represent a wide range of sociodemographic

circumstances, the findings again may not generalize to all schools in Alberta or other areas. Fifth, several variables were self-reported which likely created biases due to memory errors and socially desirable responses. It is also possible that shared method variance could have inflated the magnitude of associations between self-report variables (e.g., screen time and friend screen co-participation). Efforts were made by the research team however to minimize errors by having an evaluation assistant read aloud the survey questions to the students while they completed the survey, and having additional evaluation assistants who were available to answer questions. Sixth, in studies 2 and 3, which used an ego-network approach, dyadic clustering effects could exist that were not accounted for and which could create bias. Seventh, it is possible that other potential covariates were not included in the analyses that could explain the observed findings. For example, children may choose friends who share similar family environments (e.g., similar quality of parent support for PA).

Challenges Experienced

The greatest challenge I experienced was managing the required participation rates for social network studies, which is typically 75-80%. This is a particular concern with dyadic-level data as missing data at the individual level results in a higher proportion of missing data at the dyadic level ($N_{dyadic\text{-}level} = [N_{individual\text{-}level} - 1]*N_{individual\text{-}level}$). For example, with 80% complete data at the individual-level there is 64% complete data at the dyadic-level. This rate is difficult to achieve in studies where PA is measured using a wearable device (e.g., pedometers) because participants must wear it for enough time to represent their typical PA levels (e.g., 4 valid days; Lubans et al., 2015). Yet, in most studies, a large proportion of children do not have sufficient data. As such, I experienced a clash in practice between fields of study. If I only included schools with both 80% participation rates and 4 valid days of pedometer wear time, only 1 school would

have met the criteria. Therefore, I had to loosen the criterion for both participation rates and days of required pedometer wear. Because missing data is more of a problem at the dyadic-level, for study 1 (dyadic-level data), the participation/compliance rate was set at 50% which allowed us to retain 27 schools. The post-hoc analysis in study 1 provided evidence that these criteria did not influence the findings. For studies 2 and 3, which were individual-level analyses, the proportion of missing data was less of a concern and we only excluded 1 school due to low participation rates. Of the participants included in studies 2 and 3, we had valid data for ≥ 87% of nominated friends and thus we are confident that the majority of school-based friends were captured.

Another challenge was the collection of friendship sociometric data. Children were required to write the first and last names of their friends via an open-ended social network survey format. This created challenges when children had poor handwriting, did not report the last names of their friends and there were several children with the same first name, and when nicknames were used. Though rosters are commonly used with sociometric data and would have eliminated some of these problems (Borgatti, Everett, & Johnson, 2013), children were bringing in consent forms up to the day of data collection and so it was not feasible to create such a form at the last minute. Further, some schools had >100 grade 5 children and thus it would have been too cumbersome for children to go through such a list, especially considering the lengthy questionnaire they were already completing. Future research should develop an online system that can be easily and quickly updated (to ensure it includes all children with consent) that allows children to search for their friends in a search box by simply typing their name.

Future Research

Future research may benefit from measuring several interpersonal processes for friendship PA similarity/influence (e.g., co-participation, friend PA, encouragement)

simultaneously using social network questionnaires. These types of questions would yield more precise measures of the interpersonal processes which could be analyzed at any level (individual-dyad- or whole network-level). I was limited to measuring perceptions of the friendship group as a whole for social support (i.e., encouragement/praise, co-participation), rather than measuring social support received from each friend individually, because the questions were a part of a large survey of which I was only allotted a few pages (i.e., 10 friends x 4 questions would be 40 additional questions). Indeed, a tradeoff exists between the number of alters participants are allowed to nominate and the number of questions that can be asked about each nominated alter.

Future research should examine additional psychological mechanisms of friendship similarity/influence (e.g., competence, attitudes) to either support or refute the role of different theories, ideally using longitudinal methods. Further, because experimental research can provide the strongest evidence for causality and internal validity, such studies are also needed. Some work has demonstrated the presence of a friend or friends can increase PA levels of children in a gymnasium setting (Barkley et al., 2014; Sanders et al., 2014), which is represented in the working model as *opportunities/barriers*. Experimental manipulation of PA- and ST-related modeling, co-participation, and social support of the friendship group or one friend would also be worthwhile to demonstrate causality of these factors on children's PA and ST. Ecological momentary assessment can also allow us to examine in real time interactions with friends/peers and covariation with changes in psychological states (e.g., self-efficacy, enjoyment, competence, attitudes) and behaviour, which can provide additional evidence of causality.

New advances in technology also offer opportunities to objectively measure friendship interactions and location of co-participation, which are appealing as they can overcome limitations of survey questions that rely on perceptions. Bluetooth proximity-tagging technology

can record when children are with their friend(s) or not and the PA intensity during this time for some devices (e.g., Actigraph accelerometer). This technology has evidence of validity to detect parent-child proximity (Kuzik & Carson, in press), and has been used to measure interactions among 10-11 years-olds in the lunchroom at school (Pachucki, Ozer, Barrat, & Cattuto, 2015). Additionally, in conjunction with GPS technology, we can also objectively measure location of PA co-participation with friends (e.g., home/neighborhood, playground, recreational center, school).

Another important area for future research is a focus on children with very few or no friends. Importantly, this topic was identified by the APPLE Schools management team as an important research question as one of their principles is to ask "who is not here and why?" Though the peer-led PA interventions to date have used a whole-of-school approach to increasing PA levels of students (Bell, Audrey, Cooper, Noble, & Campbell, 2017; Sebire et al., 2018; van Woudenberg et al., 2018), when implementing friendship-based initiates isolates may need to be targeted separately as they likely interact with and are influenced little by their peers. It is important not to neglect these children as chronically friendless children are more likely to experience mental health difficulties (Hall-Lande, Eisenberg, Christenson, & Neumark-Sztainer, 2007), engage in unhealthy behaviours such as smoking (Seo & Huang, 2012), and engage in greater levels of ST (females) and lower levels of PA (males) than children with multiple friends (study 2). Additionally, a simulation study using a real-world network of children in an afterschool program found that increasing the PA of the most central children (i.e., "opinion leader" intervention) was the most effective approach to increasing the average PA levels of the whole group; however, it did not increase the PA levels of the most inactive children, thus supporting the importance of developing strategies to specifically reach these children (Zhang et

al., 2015). Higher levels of overweight, and peer victimization experienced by these children may also play a role in their undesirable levels of PA and ST (Salvy, Bowker, Germeroth, & Barkley, 2012). Though the few studies to examine negative messaging from friends (e.g., criticism, teasing) have not shown evidence for an association of peer victimization on PA (Maturo & Cunningham, 2013), these negative experiences are regarded as a key component of children's friendships (Bagwell & Schmidt, 2011), and bullying from peers is described as discouragement of PA in qualitative studies (Smith, Troped, McDonough, & DeFreese, 2015). It is possible that peer victimization negatively impacts some children but not others (i.e., overweight/obese). For instance, peer victimization has been shown to explain why overweight and obese adolescents engage in more ST than their healthy weight counterparts (Stearns, Carson, Spence, Faulkner, & Leatherdale, 2017).

Future research could also investigate whether interactions with friends' online vs. face-to-face have different implications for PA and ST in children. Interactions with friends seem to occur just as frequently or more by e-communication compared to face-to-face (Coe, Chan, & Freeman, 2016). Though the purpose and value of friendships (e.g., self-worth, companionship) is likely to remain unchanged with new technological developments, trends towards increased interactions online could have implications for how friends may influence the PA and ST of one another.

Further, a limitation of the current literature is the lack of understanding around the source and nature of friendship influences on PA and ST across childhood and adolescence (Salvy & Bowker, 2014). Though it known that peers and friends become more important over time with gains in autonomy and independence, these trends in development have received little attention in the PA and ST literature, particularly in the childhood years. Indeed, our study

suggests that friends may be important influence agents in late childhood. Thus, cross-sectionally comparing results from different age groups, or examining trajectories of change in PA across the childhood and adolescent years, would provide us with a greater understanding of when friends become significant influence agents for PA and ST and when friendship-based interventions could be the most effective. Using existing longitudinal data in Canada (Bélanger et al., 2013), I will explore co-participation in PA with influential others (i.e., friends, parents, siblings, teams) across childhood and adolescence in my postdoctoral studies.

Practical Implications

In conjunction with the APPLE Schools Management Team, I developed some recommendations for parents and schools to consider based on the findings of my studies. Parents and schools can do several things to empower children to initiate and foster healthy friendship interactions during active play and organized PA, and to discourage excessive screen use among friends. Parents can help support their child in initiating active play dates with peers and in finding the space, equipment (e.g., balls, bikes), and resources (e.g., transportation, supervision) required to do their desired physical activities. They can also allow appropriate amounts of independent mobility in the neighborhood and autonomy to interact with friends, and set daily ST limits rules around using screens when friends are over. Parents can help provide opportunities to make new friends with active peers by enrolling their child in activities at school and local community. If they have a daughter that is a part of an inactive friendship group, they should recognize that their child's friends may be discouraging their PA. Helping her find a PA that she and a friend (or friends) can enjoy doing together could be helpful. Joining an organized sport could also provide opportunities to make friends outside of their inactive friendship group from school. In general, girls tend to enjoy talking with their friends (Rose & Smith, 2009) so

encouraging some light activity with friends where they can still talk (e.g., walk the dog, to the store, or to school) is a potential strategy to get these children moving.

To take advantage of the power of friendships in shaping PA and ST, schools can offer PA events that encourage children to bring a friend or come make a friend, and that facilitate a cooperative and friendly environment. They can also provide friendship-focused messaging during campaigns and announcements, for example, by reinforcing that PA with friends is fun, and encouraging children to support each other in their PA participation (particularly for males) and in limiting ST. Schools can also specifically target female inactive friendship groups (de la Haye, Robins, Mohr, & Wilson, 2010), for example, by asking the group what activities they want to do together and offering these activities for them. Likely the most impact on screen use at school, would be for schools to create policies around limiting cell phone use during school hours, including recess and lunch, which would decrease the opportunity for screen co-participation among friends. Finally, the potential friend-to-friend influence observed in this dissertation supports peer-led initiatives currently adopted in Alberta by organizations such as Ever Active Schools and APPLE Schools. Though the motivation for these initiatives are to "get the children on board", leaders may also have a positive impact on other students by modeling, supporting, and encouraging healthy PA habits among their peers and friends. For example the Playground Activity Leaders (PALs) initiative has students lead games at recess and lunch. Another initiative is Student Wellness Action Teams (SWAT) where students co-design and lead their school's Wellness Action Plan and lead school wellness initiatives which target several health behaviours (e.g., sleep, PA, ST, diet). These initiatives could be considered a form of "opinion leader" social network interventions (Valente & Pumpuang, 2007).

Particular care should be taken for isolated children, as they tend to have low PA (males) and high ST (females). Friend benches at schools could help these children find someone to play with (Kill It With Kindness, n.d.). Games which teach cooperation, collaboration, and communication skills can be incorporated into PA programming, and the wider school can learn the importance of inclusivity and reaching out to peers who may need a friend. Such strategies could, at a minimum, offer these children more opportunity for PA (particularly important for males), and potentially steer them away from screen activities (particularly important for females).

Students as agents of change have been identified as an essential condition of successful comprehensive school health, a framework designed to transform the school culture, and which APPLE Schools is based upon (Storey et al., 2016). My dissertation offers several ideas for friendship network strategies that could empower children to be change agents within their school and contribute to a school culture of high movement and low screen use.

Conclusions

The friendship network, or lack thereof, plays an important role in the PA and ST of grade 5 children. For females, PA of friends is an important correlate of PA, and screen co-participation with friends, friend ST (paired with daily discouragement of sedentary activities), and in-isolate status are correlates of ST. For males, social support, in-degree centrality, in- and out-isolate status, and possibly friend PA are important correlates of PA, and screen co-participation with friends and discouragement of sedentary activities from friends are correlates of ST. Parents and schools need to be aware of the importance of friends in shaping healthy and unhealthy PA and ST habits at this age. This knowledge can be harnessed to create healthy

friendship interactions and influences to help establish healthy PA and ST patterns for children in late childhood.

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