Social Network Characteristics among Adolescents at Risk of Obesity: A pilot study

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PREFACE

With respect to my MSc thesis, I formulated the thesis objectives, I conducted the analyses, I led the interpretation of results, and I wrote the text. My supervisor, Dr. Tracie Barnett, developed the questionnaire, provided guidance throughout, and revised several versions of the thesis. My co-supervisor Dr. Gillian Bartlett reviewed the thesis. Committee member Dr. Peter Nugus provided conceptual guidance. Ms. Jennifer Yu assisted with the production of tables and editing. Ms. Elena Tresierra-Farbridge assisted with editing and formatting.

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ABSTRACT

Context: Youth obesity has become a global epidemic. Identification of modifiable determinants is needed to develop effective prevention strategies. The Socio-Ecological Model suggests that physical and social environments can both support and inhibit behaviours related to healthy weight. Aspects of one's personal social network (e.g. size, mode of interactions with contacts, and mean age of network members) might influence health outcomes, such as adiposity in adolescents. Social Network Analysis (SNA) is a conceptual framework, which allows us to investigate the potential relationship of social network characteristics on health-related outcomes. To this end, we developed a questionnaire designed to measure the personal social networks of adolescents and conducted a pilot study.

Objective: The main objectives were to describe the structure and characteristics of adolescents' social networks and to examine whether patterns emerged in relation to adiposity.

Methods: We conducted a SNA pilot study nested within the QUALITY study, an ongoing longitudinal study, established in 2005 and designed to investigate the natural history of obesity in Quebec, Canada (n = 630 at baseline). Data were obtained from 46 adolescents during the 3rd phase of data collection when participants were aged 15-17 years old. The outcome was participant's total body fat percentage measured by Dual-energy X-ray Absorptiometry (%BF). With respect to the SNA data collection, participants (egos) identified up to 10 friends (alters) with whom they discussed important matters. Participants also reported both their own and perceived alters' lifestyle behaviours, and connections between alters. Characteristics of alters were combined to create the following indicators of support and encouragement: Positive role models (friends who *often or sometimes* participated in physical activities and eating healthy food), of cheerleaders (positive role models who *often or sometimes* encouraged the ego to be

physically active) and negative role models (friends who *rarely or never* participated in physical activity and who *rarely or never* ate healthfully). For each indicator, proportions were computed for each ego network.

Analysis: Descriptive statistics were generated for all variables, including network- and ego-level variables. Correlations were computed between all variables, and notably with the outcome, %BF. Sex-specific multilinear regression analyses were performed to further explore the relationship between potential network features and adiposity.

Results: The final analytical sample included 28 boys and 16 girls with an average age for both of 16.3 years, and a total of 207 alters. The average %BF was 19.8% for boys and 34.2% for girls. The average proportion of cheerleaders in the network of boys was on average 0.23 and for girls an average of 0.14. Among boys, each increase in tertile of cheerleaders was associated with a decrease in the %BF by almost 8%. In contrast, a modest positive association was observed in girls.

Conclusion: Perceived behaviours and encouragement of friends may be associated with adiposity in high-risk youth, but this relationship appears to differ between adolescent boys and girls. Although longitudinal investigations are needed, these preliminary findings suggest that leveraging social networks to enhance lifestyle interventions likely need to be sensitive to gender-based beliefs.

Keywords: Obesity, adolescents, pilot study, questionnaire, weight-related lifestyle behaviours, friends, social network.

RÉSUMÉ

Contexte: L'obésité chez les jeunes est devenue une épidémie mondiale. L'identification de facteurs modifiables est nécessaire pour développer des stratégies de prévention efficaces. Le modèle socio-écologique suggère que l'environnement physique et social peut à la fois promouvoir et entraver l'adoption d'habitudes reliées à un poids santé. Certaines caractéristiques des réseaux sociaux personnels (ex. la taille du réseau, le mode d'interaction entre chaque personne et la moyenne d`âge des membres du réseau) pourraient influencer sur la santé, incluant l'adiposité chez les adolescents. L'analyse de réseaux sociaux (SNA) est un cadre conceptuel qui permet d'étudier ces caractéristiques, en identifiant les contacts sociaux (alters) des individus (egos) et en décrivant les egos et les alters, et les liens entre ego-et-alter et entre alter-et-alter. À cette fin, nous avons développé un questionnaire pour mesurer les réseaux sociaux personnels des adolescents et avons mené une étude pilote.

Objectif: Les objectifs principaux étaient de décrire la structure et les caractéristiques des réseaux sociaux d'amis des adolescents et d'explorer les associations possibles avec l'adiposité.

Méthodes: Cette étude pilote est imbriquée dans l'étude QUALITY, une étude longitudinale, établie en 2005 et conçue pour étudier l'histoire naturelle de l'obésité au Québec, Canada (n = 630 au départ). Les données du projet pilote ont été obtenues auprès de 46 adolescents (âgés entre 15 à 17 ans) au cours de la 3^{e} phase de collecte de données de l'étude QUALITY. L'issue d'intérêt était le pourcentage total de gras corporel des participants (%GC), mesuré par absorptiométrie biphotonique à rayons X. Pour la collecte des données deSNA, les participants (egos) ont identifié jusqu'à 10 amis (alters) avec qui ils ont discuté de sujets qui leur étaient importants; puis ont rapporté les caractéristiques sur leur propre mode de vie, sur leur

perception du mode de vie des alters, et enfin sur les liens entre les alters. Des indicateurs de soutien social et d'encouragement ont été créés en utilisant certaines caractéristiques des alters: les modèles positifs (amis ayant été *souvent* ou *parfois* physiquement actifs et mangé sainement), les cheerleaders (modèles positifs ayant *souvent* ou *parfois* encouragé l'ego à être physiquement actif) et les modèles négatifs (amis ayant été *rarement* ou *jamais* physiquement actifs et ayant *rarement* ou *jamais* mangé sainement). Pour chacun des indicateurs, la proportion dans chaque réseau social a été calculée.

Analyse: Des statistiques descriptives ont été générées pour toutes les variables, y compris les variables au niveau du réseau et de l'ego. Des corrélations Spearman ont été calculées pour toutes les variables, et notamment pour le %GC des participants. Enfin, nous avons effectué des analyses de régression linéaire stratifiées par sexe afin d'explorer la relation potentielle entre le réseau social réseau et le %GC.

Résultats: L'échantillon analytique finale comprenait 28 garçons et 16 filles, avec une moyenne d'âge de 16.3 ans, et un total de 207 alters. La moyenne du %GC était de 19.8% chez les garçons et de 34.2% chez les filles. La moyenne de proportion des «cheerleaders» dans le réseau social des garçons était de 0.23 et de 0.14 chez les filles. Chez les garçons, chaque augmentation du tertile des « cheerleader » était associée à une diminution du %GC de près de 8 %. En revanche, une association positive modeste a été observée chez les filles.

Conclusion: Notre étude pilote suggère que les comportements perçus et l'encouragement des amis pourraient être associés à l'adiposité chez les jeunes à risque d'obésité, mais cette relation semble différer entre les garçons et les filles. Bien que des études longitudinales soient nécessaires, ces résultats préliminaires suggèrent que l'utilisation des

réseaux sociaux pour améliorer les interventions liées au mode de vie doit probablement tenir compte des aspects liés au genre.

Mots-clés: obésité, adolescents, étude pilote, questionnaire, comportements de vie liés au poids, amis, réseau social.

Abbreviations and Symbols

BMI	Body mass index
β	Standardised regression coefficient
CI	Confidence interval
X^2	Chi-square
CPM	Counts per minute
DEXA	Dual-energy X-ray absorptiometry
IQR	Interquartile range
MVPA	Moderate-to-vigorous-physical activity
OW	Overweight
P	Probability
PA	Physical activity
QUALITY	Quebec Adiposity and Lifestyle Investigation in Youth
ρ	Correlation coefficient (rho)
SD	Standard deviation
SN	Social network
SNA	Social network analysis
QUALITY V3	Third wave of data collection for the QUALITY cohort study

Tables and Figures

1. INTRODUCTION

Youth obesity is a widespread epidemic in the present-day world, with over 124 million children aged five to 19 years struggling globally with this condition (1). In the United States, one in five school-age children (6-19 years) were obese in 2016 (2); in Canada, based on Canadian Health Measures Survey data, one in seven Canadian children between the ages of two and 17 years were categorized as obese in 2012-2013 (3). The United Kingdom and other European countries are facing similar trends of increasing childhood obesity (4-7). This problem has extended to children in developing countries as well (8-10).

Increasing obesity among children and adolescents is concerning as it affects their physical and psychological development and wellbeing. Children who remain obese across the childhood period are at higher risk of developing cardiovascular disease in adulthood (11-13). Obesity in childhood and adolescence is also associated with an increased risk of premature mortality in adulthood (11, 12, 14), and with an increased risk of developing hypertension, type 2 diabetes, and dyslipidemia, obstructive sleep apnea (15). Children with obesity are more likely to suffer from depression, anxiety, low self-esteem, and bullying, all of which adversely influence the quality of their lives (16, 17).

Several behavioural determinants of obesity have been established, including energy-dense and nutritionally poor dietary patterns (18, 19), short sleep duration (20-23), low levels of physical activity (24), and excess sedentary behaviour (25). Notably, consumption of sugar-sweetened beverages and foods rich in saturated and trans fats have been associated with weight gain while foods such as whole grains, fruits, and vegetables have been linked with weight loss and maintenance (19) . Shorter than standardized reference sleep duration for child age, and poor-quality sleep independent of sleep duration increase risk of overweight (OW) and obesity in

children and adolescents (20-22). Sedentary behaviours such as television viewing more than 2 hours/day contribute to overweight and obesity 1.90 times compared to less than 2 hours/day independent of physical activity in children 8-11 years (25). Proximal social determinants of obesity include family-level socio-economic status, and family and peer influences (26-29). Low socioeconomic status can be a risk factor for childhood obesity in both high and low-income countries (29).

A recent seminal paper framed obesity as a socially contagious condition that can be "*transmitted*" through social contacts. Christakis and Fowler described a direct person-to-person spread of obesity in a large social network of adults, observing that the likelihood of becoming obese increases if a close friend became obese over a given period (30). There is also evidence to suggest that social networks may be implicated in the development of adolescent adiposity, given that obese adolescents are more likely to have obese friends in their personal social networks than those who are not obese, but the underlying dynamics remain unclear (31-33).

While the mechanisms are complex and remain to be fully elucidated, it is likely that family and friends partly influence obesity through similar weight-related behaviours including, eating, exercising, and sedentary pursuits. Social groups tend to be structured around everyday activities, including those focused on eating and on both sedentary and active leisure pursuits, most of which impact energy-balance (i.e. intake and expenditure) and subsequent weight status.

It is also likely that homophily, or our tendency to prefer others who look and behave similarly to us, partly explains Christakis and Fowler's findings, (34, 35). Nevertheless, the potential role of social networks given the current obesity epidemic is intriguing and warrants greater understanding.

A useful framework in which to investigate the relationship between social networks on weight-related outcomes is the socio-ecological model. The model incorporates several levels of influence that are represented in the form of concentric circles (Figure 1) (36); these include individual characteristics, relationships with family and friends, and broader contextual influences. Key to the model is the understanding that health behaviours are subject to multiple influences that can interact with both supportive and inhibitive weight-related behaviours (37).

Throughout the life course, those factors that are most implicated in the development of obesity evolve. While social influences are pervasive throughout childhood and into young adulthood, adolescence is a critical age in which to explore social influences as teenagers typically try to disassociate or create distance, from their parents or primary caregivers, allowing greater importance to social bonds in their peer networks (38). Investigating patterns within adolescent social networks and the weight-related behaviours of their network members may help elucidate the possible underlying mechanisms and could potentially inform novel strategies targeting healthy weight promotion (39).

To this end, a pilot study was conducted among 46 randomly selected adolescents at risk of obesity, primarily to inform a subsequent study involving a lifestyle intervention for overweight youth. Objectives pursued prior to the current thesis related to feasibility of collecting data; face and content validity of the measures; variation and missingness of specific variables; and creation of composite indices (40). In the current thesis, we adopt an exploratory posture as we describe potential patterns in the data. Although no specific hypotheses were proposed, we sought to explore relationships between selected features of social networks and adiposity in adolescents. Hence, the main objectives of this thesis are **to describe the structure and characteristics of the social networks of participating adolescents and to examine**

whether patterns emerge in relation to adiposity. While findings will inform the process of the aforementioned future large-scale prospective investigation and may generate hypotheses, the focus of this thesis will be on the quantitative results that emerge.

2. LITERATURE REVIEW

In this section, I define obesity, review the epidemiology of obesity in youth including prevalence, consequences, and determinants, with an emphasis on the role of social networks in obesity and obesity-related behaviours. I also provide a conceptual framework and an overview of social network analysis.

2.1 Obesity

2.1.1 Definition of Obesity

The World Health Organization (WHO) defines obesity as "*abnormal or excessive fat accumulation that presents a risk to health*" (41). The most practical and therefore common way to identify obesity is with the use of the body mass index (BMI) (41). Since weight is dependent on the body's ability to grow in children and adolescents (up to age 19 years), age in months from birth to 36 months and age in years from 2 to 19 years and sex-specific weight norms exist. Based on these norms, children with a BMI that is equal to or greater than the age- and sex-specific 95^{th} percentile are considered obese, whereas those with a BMI between the 85^{th} and 95^{th} percentile are considered overweight (42).

2.1.2 Prevalence of Obesity

The prevalence of obesity has been steadily increasing in both developed and developing nations. In the United States, the number of obese children has doubled, and the number of obese adolescents has quadrupled in the last three decades (43). Recently, a large epidemiological

study conducted by the Imperial College in London, UK, in collaboration with the WHO on measurements of age- and sex-standardized mean BMI collected data from approximately 2416 population-based studies. Their analysis shows a tenfold increase worldwide in obesity prevalence among children and adolescents between the ages of five and 19 years, in the past four decades, from 11 million in 1975 to 124 million in 2016 (44, 45). The highest prevalence in 2016 was found in the Polynesian and Micronesian islands, which are low-income countries, followed by high-income countries like the United States and Canada (44, 45). While initially considered a condition endemic to high-income developed nations, obesity trends now reflect that prevalence is highest among under-developed and economically compromised countries.

In Canada the prevalence of childhood obesity tripled during the period from 1981 to 2012 (46), and based on the 2009/2011 Canadian Health Measures Survey the pediatric population and the WHO BMI cut points data, about 20% of Canadian school-aged children are overweight, and an additional 12% are obese, with almost 1 million overweight and 600 000 obese school-aged children (47).

2.1.3 Complications related to Obesity

Obesity has been associated with increased risk of cardiovascular and other non-communicable diseases such as type II diabetes (12, 48). High levels of adiposity during childhood and adolescence are associated with an increase in inflammation, oxidative stress, and endocrine dysfunction in childhood and adulthood (12, 49). Adults and youth who were obese in their childhood are at a higher risk for developing cardiovascular conditions like early atherosclerosis, stroke, and ventricular hypertrophy, dilation and dysfunction (12). The metabolic malfunction in obese children also leaves them at high risk for diabetes, insulin resistance, and hyperlipidemia (48). Chronic obesity and weight gain in children and youth are also directly

associated with worsening life expectancy in adults (11, 12, 14). Additionally, some studies have focused on the psychosocial consequences of childhood obesity; more specifically, childhood obesity has been linked to attention deficit hyperactivity disorder, bipolar disease, depression, and anxiety (11, 12, 14) potentially due to weight-related social stigma, teasing, and bullying (16).

2.1.4 Assessment of Obesity

The most widely used measure for identifying obesity is the body mass index (BMI), defined as a person's body weight divided by the square of his or her height (kg/m^2) (50). Other anthropometric indices used to measure obesity include waist circumference, waist-to-hip ratio, and waist-to-height ratio (51, 52). These indices focus not only on total body weight but also on its distribution and location of body fat. In particular, visceral fat accumulation is associated with an increased risk of hypertension, diabetes, and other metabolic disorders; hence, waist circumference and waist-to-height ratios are considered more discriminatory and sensitive in their measurement of obesity when compared to BMI (52, 53). However, the correlation between waist circumference or waist-to-height ratios with BMI is over 90% (54).

Other methods for classifying obesity include bioelectric impedance analysis (BIA) and imaging via Dual-Energy X-ray Absorptiometry (DEXA) (52). While the former is credited for being non-invasive compared to DEXA, biometric impedance measurements are highly sensitive to surrounding environmental conditions and are usually not as accurate as imaging techniques. BIA is based on measuring resistance to a low level of electrical currents that pass through different types of body tissues to calculate the percentage of body fat and fat-free mass (55). DEXA uses two X-ray beams of different energy levels that undergo various levels of attenuation as they contact bone, body fat, and non-fat tissue, providing estimates of whole body

fat-free mass, fat mass, and bone mineral density (52). Compared to BMI, DEXA is more accurate for measuring obesity but is rarely used as it is much more costly and inconvenient. Given its convenience and simplicity, BMI remains the method of choice for population-based studies (56, 57), but adiposity ascertained with DEXA is considered to be more accurate, particularly in developing adolescents.

2.2 Conceptual Framework

Social Ecological Model (SEM) is a theory-based framework that incorporates the reciprocal interaction of individual behaviours and the environment in the development of obesity. The model purports that weight status is influenced by the energy intake and expenditure patterns of individuals, with these behaviours embedded within a broader ecology (58). Multiple concentric layers of influence include intrapersonal, family and peers, community, and societal, factors (Figure 1) (58). The intrapersonal or individual-level aspects include biological factors like genes, age, sex, and ethnicity, as well as modifiable factors such as knowledge, attitude, beliefs, socio-economic status and others. The interpersonal level includes social networks that might have positive or negative influences on an individual's health behaviours including family, close friends, peers, or religious affiliations (58). The community level can include educational, commercial and civic services, transport infrastructure, and built environment features such as green spaces and recreational areas that adolescents may frequent (59). Finally, societal factors may include policies and regulations, but also cultural norms about weight and weight-related behaviours. Within the SEM, social networks allow for both individual and environmental influences and are well suited to the aims of the current thesis.

2.3 Risk factors for Obesity in Youth

Obesity is a complex condition, with risk factors at multiple levels of influence. While these are briefly summarized, I focus primarily on those that are most relevant to my study aims. Individual determinants include genetic factors (60-63), lifestyle behaviours including poor dietary habits (64), excess sedentary behaviours (25, 65), physical inactivity (66), and inadequate sleep (67-69). There is a consistent social gradient in obesity, observed with respect to household income and parental employment status (70); parental education attainment, and health literacy (71); food insecurity and housing (72); and social isolation (73).

Built environment features associated with obesity include urban sprawl, diversity of destinations, food sources, and access to facilities for exercise, all of which can influence weight-related lifestyle behaviours such as physical activity and nutritious diets (18, 74, 75).

Higher levels of physical activity are generally protective against obesity and its consequences in adolescents (76-78). Engaging in sedentary pursuits such as watching television or spending time on tablets and phones (screen time) for excessive periods of time are important determinants of obesity in children and adolescents (65, 79).

Poor dietary patterns and ingesting excessive quantities of food are two established determinants of weight gain and obesity. In particular, consumption of high glycemic index foods, larger-than-appropriate portion sizes, sugar-sweetened beverages, fast food rich in saturated fat and less frequent family meals have been linked to significant weight gain (15, 19, 80). Conversely, consumption of whole grains, fruits and vegetables, and fibre-rich foods, in addition to controlling portion sizes, protects against excess weight gain (81).

2.3.1 Social Environment

The social environment of children and youth is largely defined here by those individuals who directly interact with them and can potentially influence their health behaviours, such as parents, friends, and other significant persons in their surroundings. This core group can establish norms that shape beliefs, perceptions, expectations, and behaviours, and ultimately, their subsequent risk of becoming obese (82).

Throughout their lifetime, individuals are exposed to a variety of settings in which they have the opportunity to observe or interact with people with more or less healthful lifestyle behaviours. Parents may play a larger role in shaping younger children's behaviour, but their influence tends to wane throughout adolescence, as influence from friends and peers increases (83-85). Developmental theories put forward in the past decade suggested that the number and frequency of peers and peer interactions increase as one approaches young adulthood (86). Adolescents spent more time with their friends from their neighbourhood, school, or university, and these friendships are perceived by them to be the most meaningful (87, 88). Moreover, adolescents take on new and more complicated social roles and responsibilities and begin to develop a sense of identity of their own. Also, youth identity and self-evaluation depend on peer feedback, with adolescents' behaviours tending to conform to peer norms (86).

Peers tend to have similar general beliefs, including academic motivation and prejudice (89, 90). Close friends tend to have a more significant influence on behaviour than a broader group of acquaintances (91-93). Friendship network features are significantly correlated with a vast number of health-related behaviours among adolescents, suggesting a possible role of influence. For example, friends' eating behaviours such as dietary restraint, extreme weight loss

behaviours, and binge eating were found to be similar to one another's, especially among middle school girls (94).

In addition to closeness, the quality of friendship may influence how social networks affect adolescents' coping styles, which may be particularly important for those affected by obesity. Compassionate and supportive friends can reduce perceived social stigma and increase adolescents' self-efficacy to participate in physical activity (95). On the other hand, conflictual and non-supportive peers or friends tend to increase self-blame behaviours among adolescents and reinforce negative ideas and attitudes toward health-related behaviours (95).

In summary, friends can have a substantial influence on the behaviour of adolescents and may, therefore, be associated with both health-promoting and health-damaging effects; social network analysis (SNA) is a useful approach to study these dynamics empirically.

2.4 Social Networks

A social network is defined as "*a social structure consisting of individuals, who have a direct or indirect relationship between them depending on a particular interest, e.g. friendship*" (96). The relationship between social networks and the development of overweight and obesity is complex and involves a number of interrelated social mechanisms, including contagion or influence (most likely by modelling one's behaviours in order to conform with others' behaviours, consciously or not) and social selection (i.e. choosing friends that are similar to ourselves with respect to levels of physical activity, weight status, etc) (27). However, over time, the distinction between contagion and selection becomes less meaningful; even if ties were grounded in selection initially, the dynamic nature of relationships leaves ample opportunity for potential influences to emerge.

2.5 Overview of Social Network Analysis

Social network analysis (SNA) is a methodological tool to study the features of inter-connected relationships, including their structure and composition (97). There are two main types of networks in SNA: sociocentric networks, also called whole networks, and egocentric social networks, also called personal social networks (98). **Sociocentric** or **complete networks** "*consist of the relational ties among members of a single, bounded community*" (98) such as all students in a classroom. **Egocentric networks** are focused on a key person of interest (ego), and are comprised of individuals named by the ego (alters) (99, 100). Members in an ego-network may belong to any of multiple social settings. We focus exclusively on egocentric networks given the interest on individual determinants (e.g., frequency, context and mode of interactions; in contrast, sociocentric SNA tend to focus on network-level influences, structures, and outcomes such as concentration of power, resource distribution, or diffusion of information. Data collection for ego-networks is most commonly done with specific participants (egos) using paper-based or online questionnaires, with or without assistance. First, a "*Name Generator*" is applied, i.e., a question used to elicit the names of ties or "alters: linked to the ego according to specific criteria, such as those they feel close to, discuss important matters with, or see frequently. The number of alters may be constrained (e.g. 3 closest; up to 10) or may be unlimited. "*Name Interpreter*" questions are then used to collect information on attributes of alters such as socio-demographic characteristics, and lifestyle behaviours. Items on the relationship between ego and each alter are also typically included, such as how close they are, and the frequency and mode of contact. Finally, egos report the existence and strength of alter-alter relationships.

Ego reported data can be used to create social network indicators that describe the structure, composition and dynamics of the networks, including network size, density, and centrality (see Glossary of terms in Supplementary Tables). The network size is the number of alters involved in the network (101). **Components** are defined as subsets of alters connected to each other but disconnected from other alters absent the ego (see figure 2). Alters that are not connected to any other alters in the network are called *isolates*. Since isolates stand alone, they are each, by themselves, a component. Homophily refers to the idea that egos will form ties with people who have similar characteristics as themselves (98). **Density** is the proportion of existing ties over all possible ties between alters. If every alter is tied directly with every other alter in the network, the density is one hundred percent.

2.6 The Role of Social Networks in Obesity and Obesity-related Behaviours

In the last decade, there have been several studies conducted that show the significance of social networks in individuals' weight-related behaviours (30-33, 94, 102-112). While most show evidence of clustering of behaviours, it is unclear if adolescents tended to form social networks with other adolescents having similar physical and behavioural traits (i.e. homophily) (32, 33, 94, 102-106, 110, 113), or if their ego's weight-related behaviours became more similar to those of their network over time (i.e. induction) (30, 108, 109, 112). Longitudinal studies can provide some evidence of the latter, but the dynamics are unclear in most cross-sectional studies.

During adolescence, individuals take on new responsibilities, have new experiences, and develop their identity. The need to adhere to social norms and find social acceptance is strong, and adolescents tend to form ties with others who share similar interests and practices (114). The literature provides ample evidence that friends and peers cluster with respect to weight-related behaviours. Barclay and colleagues examined a sample of 5,695 adolescents in Sweden to

describe the ego-alter relationships with diet and physical activity patterns (102). In a sub-analysis among ego-alter dyads, egos had a greater likelihood of eating healthy and of following physically active practices if their alters engaged in healthy lifestyles, and vice versa.

In the National Longitudinal Study of Adolescent Health (Add Health), which included 58,987 students from 88 US middle schools and high schools, social network analysis was used to show that weight status predicts the selection of friends, underscoring the notions of homophily and the social marginalization of obese and overweight youth (103). The study found that both homophily and avoidance concepts were noticeable with healthy-weight adolescents who had a preference for normal-weight friends. Adolescents with excess weight were more likely to be nominated by adolescents with excess weight than by adolescents with healthy weight, suggesting that BMI was a significant determinant of friendship nomination among middle- and high-school students (103). Over time, relationships between dissimilar people are more likely to dissolve than those among similar people (similar BMI, and or activity levels) (109). In an Australian study of 378 adolescents, those who were involved in sports tended to choose friends performing similar activities over their more sedentary peers (113), supporting the idea that selection (i.e. homophily) is at least partly responsible for similarities in behaviours.

In a seminal study based on data from the Framingham Heart Study that included a densely interconnected group of 12,067 people followed over 32 years, obesity appeared to ‘spread’ through social ties. Specifically, being connected to a friend, sibling, or spouse with obesity increased the risk of becoming obese over time (30). Although disentangling homophily from influence is not generally possible, evidence from longitudinal studies suggests that at least some of the substantial clustering observed is due to influence.

2.6.1 Online Social Networks

With the advent of Facebook, Twitter, and other online social networking platforms, the nature of the social network and its levels of influence has widened significantly. Easy accessibility of these platforms on different devices – mobile phones, tablets and computers – means that people can be connected to others all day, every day. Children and adolescents spend a significant portion of their lives on such social platforms, making them highly susceptible to social network influences (115).

A prospective study using online social network data found that the greater the online network ties with others promoting smoking cessation, the higher the chances for abstinence from tobacco use (116). Although distinct from social networks per se, online networking platforms can be instrumental in the maintenance of relationships within personal social networks, notably by facilitating interactions between members, potentially helping to bring about behavioural change. A review of studies focusing on the use of social media in promoting health equity found that online networking and discussions were especially beneficial for adolescents, seniors, and people from a lower socio-economic background (117).

3. OBJECTIVES

Obesity is a complex condition, and its prevention and treatment require a greater understanding of social influences. Recent research provides compelling evidence that friends and peers may be implicated in the development of excess weight, but to our knowledge, no studies have investigated this link using SNA among Canadian youth considered at high risk of obesity. To this end, a pilot study was conducted among 46 randomly selected adolescents at risk of obesity, primarily to inform a subsequent study involving a lifestyle intervention for

overweight youth. Objectives pursued prior to the current thesis related to feasibility of collecting data; face and content validity of the measures; variation and missingness of specific variables; and creation of composite indices (40). In the current thesis, we adopt an exploratory posture as we describe potential patterns in the data. Although no specific hypotheses were proposed, we sought to explore relationships between selected features of social networks and adiposity in adolescents. Hence, the main objectives of this thesis are to describe i) the structure and characteristics of the personal social networks of adolescents with a parental history of obesity, and ii) the patterns emerging between network features and adiposity, as assessed using DEXA. While findings will inform the process of the aforementioned future large-scale prospective investigation and may generate hypotheses, the focus of this thesis will be on the quantitative results that emerge.

4. METHODOLOGY

4.1 Overview of the QUALITY Cohort Study and Social Network Pilot Study

The Quebec Adiposity and Lifestyle Investigation in Youth (QUALITY) study is an ongoing prospective cohort study investigating the natural history of obesity and Type 2 diabetes mellitus (118). Families in QUALITY were recruited through schools located within 75 km of Montreal, Quebec City and Sherbrooke (Canada). Baseline data were collected from 2005-2008; a first follow-up was completed in 2011, and a second in 2015. Eligible participants of QUALITY consisted of Caucasian children of Western European ancestry (restricted by design to decrease genetic admixture) aged 8–10 years, with at least one obese biological parent (i.e.BMI $\geq$ 30 kg/m^2 or abdominal waist circumference $\geq$ 102 cm for men or $\geq$ 88 cm for women based on self-reported measurements of height, weight and waist circumference). Both biological parents had to be available to participate in the baseline assessment.

Baseline data were collected between September 2005 and December 2008, when participating children were between the ages of eight and ten years. Complete data were collected in 630 families. Approximately 89% of participants were involved in the 1st follow up when they were between the ages of 10 and 12 years and 60% participated in the 2nd follow up when the participants were between the ages of 15 and 17 years. Families were not eligible to participate in the study if the mother was pregnant or breastfeeding at the baseline evaluation, or if the family had pending plans to move out of the province of Quebec. Children were also excluded if they had any of the following conditions:

(i) a previous diagnosis of type 1 or 2 diabetes;

(ii) a severe illness, psychological disease, or cognitive disorder that hindered participation in some or all of the study components;

(iii) treatment with anti-hypertensive medication or steroids (except if administered topically or through inhalation); or

(iv) adherence to a very restricted diet (<600 kcal/day).

At each wave of data collection, participants took part in a full-day visit at the L'*Unité de recherche clinique du* Centre Hospitalier Universitaire (CHU) Sainte-Justine in Montreal and Hôpital Laval in Quebec City. Data collected included interviewer-administered questionnaires for children, self-administered questionnaires for parents, biological and physiological measurements for both children and their parents, and other objective measures such as monitoring of physical activity using accelerometry.

De novo social network data collecting for the current pilot study were included as an "add-on" project pilot during the final year of the 2nd follow up. The remainder of this thesis focuses on the findings emerging from the pilot study data, which included 46 QUALITY

participants. Where pertinent, variables collected in the primary data collection were also retained for analysis, such as measured body composition.

4.2 Design

The pilot study was embedded within the ongoing QUALITY longitudinal cohort study, but all the data used in this project were collected during a single time point, i.e. at the 2nd follow-up, when participants were 15-17 years old. The study design is therefore cross-sectional.

4.3 Study Sample

During the last year of data collection for the 2nd follow up, in the summer of 2016, all participants were invited to complete the Social Network Questionnaire add-on; approximately every second adolescent that was approached consented to participate. Most who refused did so because of a lack of time. Overall, of the approximate 100 adolescents systematically approached and invited to participate in the pilot study, a total of 46 participants completed the questionnaire, 28 boys and 16 girls.

All participants provided written consent (Appendix I). Ethical approval for this pilot study was obtained from the Ethics Review Boards of the Sainte-Justine University Hospital Center and the Quebec Heart and Lung Institute.

4.4 Data Collection Procedures

4.4.1 Social Network Questionnaire

Instrument: Social network information was collected using a self-administered questionnaire on paper (Appendix II). All questionnaires were filled out by the participants at the *L'Unité de recherche clinique du* Centre Hospitalier Universitaire (CHU) Sainte-Justine in Montreal.

Participants (i.e. "*egos*" in social network terminology) were asked to provide up to 10 names of friends or relatives (i.e. "*alters*"), using the following "*name generator"* question: "*Over the past year, with whom did you discuss things that are important to you? You can list up to 10 people*".

Details about each alter were then solicited using "*name interpreter*" questions. In addition to responding to questions about themselves, participants were asked to report characteristics on each alter, including age, sex, lifestyle behaviours (including frequency of physical activity, recreational Internet use, and healthful eating, with possible answers for each: never, rarely, sometimes and often). Participants were also asked to report characteristics of the relationship or "*tie*" with each alter, including the relation type (e.g. parent, sibling, friend, etc.), modes of contact (any of: in-person, phone, email, text messaging, social media messaging such as Facebook and Snapchat, video chat such as FaceTime and Skype, and other mode of contact), and frequency with which the alter encouraged the ego to be physically active (possible answers: never, rarely, sometimes, often). Finally, participants then reported on the nature of the connection between alters, and indicated, for each pair, whether alters knew each other well, knew each other only a bit or did not know each other.

Although all relationships were inquired about, our interest was in friendship networks for the current thesis, so we purposefully excluded parents, grandparents, and other older adults and limited the social networks to alters of similar age, including relatives and friends within five years of the ego's age.

4.4.2 Other Collected Data

Some variables relevant to this thesis were obtained from the primary QUALITY study data collection. These included ego-level socio-demographics (age, sex, parent's level of

education, dichotomized as at least one parent with a university degree versus neither), indices of adiposity, and objectively measured physical activity.

Physical activity level was measured using Actigraph accelerometers (Actigraph LS 7164 activity monitor, Actigraph LLC, Pensacola, FL, USA) in the week following the clinic visit (119). Participants received instructions requiring them to wear the accelerometers on the hip for seven consecutive days and for at least 10 hours a day. Data were valid if accelerometers were worn for $\geq$ 4 days and $\geq$ 10 hrs/day. The threshold for MVPA was set as $\geq$ 2,296 counts per minute (cpm) (120), and average daily minutes of physical activity was computed.

4.5 Study Variables

4.5.1 Main Outcome: Adiposity

The outcome variable was % total body fat as measured by DEXA imaging, which was standardized to facilitate interpretation (GE Prodigy Lunar, Madison, WI, USA) (121).

4.5.2 Main Independent Variables

Social Network Structure

The variables relevant to the analysis of this study, as well as how they were created, are defined below and illustrated in Figure 2.

Network size: The network size is defined as the total number of alters nominated by the ego and ranges from 0 to 10 alters for each ego.

Density: The density of a social network is defined as the number of existing ties between alters over the number of possible ties. The equation used for density was:

$$D = \sum^{i,j} \frac{a_{ij}}{(n \times (n-1))/2}$$

a_{ij} is the link between alters i and j (values of 0 or 1), and n is the number of alters in the network. Values range from 0 to 1, where 0 indicates that none of the alters are connected to each other, and 1 when all of the alters are connected to each other (i.e. know each other a bit or very well).

Component: The number of components was defined as the number of subgroups of inter-connected alters or isolates.

Isolate: An isolate was defined as an alter without any ties to other alters in the network.

Social Network Composition

The social network composition variables are ego-specific aggregates of alter characteristics (e.g. mean age, proportion living nearby). The main composition variables of interest for the current thesis were indicators based on multiple alter attributes that pertained to social support via modelling or encouragement. We describe them below, using meaningful labels including "cheerleader," "positive role model," and "negative role model."

Indices:

Positive role models: This variable was created based on alters lifestyle physical activity and dietary behaviours; we defined an alter as a positive role model if he or she *often or sometimes* engaged in physical activity and *often or sometimes* ate healthfully. For each ego, the proportion of positive role models over the total number of alters in his/her social network was calculated. Values ranged from 0 to 1, where 0 means having no positive role models in the network and 1 means having the entire network be positive role models. For regression analyses, proportions of positive role models variable were transformed into categories, where the lowest one had a value of 0, the middle one a value from > 0 to < 0.5 and the highest one a value of ≥ 0.5.

Cheerleaders: This variable was defined as a positive role model who additionally *often or sometimes* encouraged the ego to be physically active. We calculated the proportion of cheerleaders for each ego, with values ranging from 0 to 1, interpreted as above. Approximate tertiles were defined by values at 0, from > 0 to < 0.2405, and ≥ 0.2405.

Negative role models: This variable was defined as friends *who rarely or never* participated in physical activity and who *rarely or never* ate healthfully. The proportion of negative role models over the total number of alters was calculated for each ego. Values ranged from 0 to 1, 0 for having no negative role model friends and 1 for having the entire friend group be negative role models. The proportion of the negative role models was also categorized into approximate tertiles, defined by values at 0, from > 0 to < 0.25, and ≥ 0.25.

Finally, participants were asked to report various modes of contact with each alter. For the current thesis, we retained only the proportion of alters with whom the ego interacted face-to-face.

4.6 Statistical Analyses

Descriptive statistics included means, standard deviations, medians, and ranges for sociodemographic characteristics (age, sex, parent education), total body fat percentage, and average daily MVPA variables. Simple imputation was used for those with missing MVPA, by sex. Socio-demographics, adiposity and weight-related behaviour characteristics were compared between participants of this pilot study and the eligible participants, i.e. the full second follow-up of QUALITY cohort data collection. No specific hypotheses were tested given the exploratory nature of the pilot study; patterns suggesting possible associations and mechanisms were

examined. Consequently, results are hypothesis-generating only, and findings are to be interpreted with caution.

A comparison between boys and girls of the pilot study was performed. By convention, group differences were tested with a two-tailed T-test for continuous variables, and Pearson's chi-square test (χ^2) for categorical variables. Spearman correlations were executed for each pair of studied variables, to discern potential factors associated with the outcome, i.e. the percentage of total body fat. Due to the exploratory nature, correlations of 0.2 or higher were considered to be of potential interest. Multiple linear regressions were performed, including apparently correlated factors. Variables correlated with a value ρ of more than 0.6 were not included in the same regression model to avoid multicollinearity issues. All models were controlled for age, network size, and parental education, and stratified by egos' sex. The R statistical software was used for all analyses, including computing social network variables, descriptive, correlation and regression models, and for generating network figures (122).

5. RESULTS

The initial sample for this study included a total of 46 consenting participants, who completed questionnaires about their social networks, and provided information on a total of 306 alters. Two participants who did not have any same-aged peers in their network were excluded. Because the focus was on same-aged peers, which we defined as relatives or friends that were within five years of the age of the participant, the final analytic sample included 44 participants, and a total of 207 alters.

5.1 Descriptive Results

<u>Sample characteristics:</u>

The characteristics of the SNA pilot sample and all the eligible QUALITY cohort participants at the 2nd follow up are shown in Table 1. The pilot study had 46 adolescents with a mean age of 16.4 (SD= 1.1), and 65% of the sample were boys. Approximately 61% of participants had at least one parent with a university degree. Demographics including age, sex, and parent education were similar between the social network study sample and the QUALITY cohort. Also, despite the small sample and the missing values for 25% of participants, their average daily minutes MVPA was comparable to those of the QUALITY cohort. Total body fat percentage was slightly lower in the pilot sample, in comparison with the full cohort (25.35 (SD=12.45) vs 27.88 (SD=11.74), respectively).

The distribution of demographic characteristics and weight-related behaviours (including average daily MVPA, self-reported physical activity, recreational Internet use, caring about eating healthy) of the pilot study participants are presented by sex in Table 2. The median age for both sexes was 16.3 years. Mean total BF% was 19.8 (SD =10.9) for boys and 34.2 (SD = 9.3) for girls. Based on accelerometry measures, boys engaged in 28.6 minutes of daily MVPA on average, while girls engaged in 15.5 minutes of daily MVPA on average. Boys were more likely than girls to report that they were sometimes or often physically active (82% vs. 68.8%), but girls were more likely than boys to report that they sometimes or often ate healthfully (81.3% vs. 53.6%).

Social Network Characteristics:

Social network characteristics are presented in Table 3 for all participants, and by sex. We generated p-values given that our sample, although small, was randomly selected; however, these are presented by convention and for illustrative purposes, and not as formal hypothesis testing criteria. The mean number of friends named by the egos (network size) was 4.7 (SD=

2.5). Girls tended to name more friends than did boys [5.7 (SD = 2.6) vs. 4.1 (SD = 2.4)]. Also, the mean of social network density for all egos was 0.9 (SD=0.4). Girls' social networks were denser than those of boys, with respective averages of girls 0.8 (SD=0.3) and 0.7 (SD=0.4), suggesting that girls' friends were more likely to be each other's friend as well. For all egos, the mean number of components was 1.3 (SD=0.6) and the mean number of isolates 0.4 (SD=0.8), albeit values were higher in boys than in girls, which is to be expected given the higher density among girls.

Although higher in girls, both boys and girls had face to face interactions with the vast majority of alters. With respect to indicators capturing (positive and negative) role modelling and encouragement, the patterns that emerged were generally similar in boys and girls. Specifically, the overall mean proportion of perceived negative role models (i.e. friends who were rarely or never physically active and who rarely or never ate healthfully) was 0.18 (SD=0.30), while the mean proportion of alters who were perceived to be positive role models (i.e. friends who often or sometimes engaged in physical activity and who often ate healthfully) was 0.32 (SD=0.30). In contrast, the mean proportion of perceived cheerleaders (i.e. positive role models who often or sometimes encouraged the ego to be physically active) 0.19 (SD=0.29) appeared to be higher in boys than in girls [0.23 (SD=0.33) vs 0.14 (SD=0.19)].

5.2 Correlations

Table 4 presents the pairwise Spearman correlation matrix for the 17 study variables retained including 1) study outcome (standardized total body fat percentage); 2) socio-demographic characteristics (age, sex, parent education); 3) ego weight-related behaviours (frequency of ego self-reported physical activity, frequency of ego self-reported recreational internet use, frequency of ego self-reported eating healthy, and ego average daily MVPA); 4)

network composition (mean proportion of positive role models, mean proportion of cheerleaders, mean proportion of negative role models); and 5) network structure (size, density, components, and isolates). Correlation coefficients were generally low, except for related indicators (e.g. mean proportion of positive role models and mean proportion of cheerleaders (ρ =0.77), or density and number of components (ρ = -0.66). Interactions with friends was weakly correlated with ego's average daily MVPA (ρ = 0.12).

Table 5 only shows correlations including the outcome, total body fat percentage. Notable inverse correlations were observed for the following variables: ego self-reported physical activity frequency, ego average daily MVPA, proportion of positive role models, and proportion of cheerleaders. Conversely, the proportion of negative role models was positively correlated with ego adiposity.

5.3 Multilinear Regression Analyses

Table 6 summarizes the results of the sex-specific multiple linear regression models describing the relationship between social network characteristics and participant adiposity. All variables correlated with adiposity at a coefficient of 0.2 or higher were included initially in the models. After excluding those that were highly correlated with others in the model, variables retained included MVPA, the proportion of cheerleaders, and network size. Among boys, each increase in tertile of cheerleaders was associated with 8% decrease in the percentage of total body fat. There was no such association observed among girls.

Table 1. Characteristics of QUALITY social network pilot study participants and of the complete QUALITY cohort, QUALITY Social Networks pilot study, Montreal, Quebec, Canada, 2016 (n =46)

Characteristics	Pilot N=46 (100%)	QUALITY[1] N = 377 (100%)	P-value for difference
Age (years)		**N=377**	
mean (SD)	16.4 (1.1)	16.8 (1.67)	0.23
median	16.0	16.68	
IQR	3.0	1.67	
Sex[2] (boys), n (%)	30 (65)	204 (54.1%)	0.17
Parent education[2]	**N (%)**	**N (%)**	
parents not university educated	18 (39.1)	287 (45.4)	
at least one parent with a university degree	28 (60.9)	341 (54.0)	0.55
missing	0	4 (0.6)	
***Total body fat (%)**		**N=377**	
mean (SD)	25.35 (12.45)	27.88 (11.74)	0.14
median	25.92	29.27	
IQR	18.99	18.05	
Missing n (%)	0	2 (0.53)	
WHO-standardized BMI z-score			
mean (SD)	0.75 (1.3)	0.75 (1.27)	0.74
median	0.67	0.67	
IQR	1.78	1.78	
****Average daily MVPA (minutes)**		**N = 377**	
mean (SD)	24.90 (19.69)	26.95 (18.13)	0.50
median	20.67	22.43	
IQR	19.04	23.54	
Missing n (%)	11 (25.00)	146 (39.00)	

SD, standard deviation, IQR, interquartile range. All variables self-reported unless otherwise indicated. *derived from DEXA **derived from accelerometers. [1]V3 QUALITY data. [2] Pearson's Chi-square was used to calculate the difference.

Table 2. Participant characteristics, all participants and stratified by sex, QUALITY Social Networks pilot study, Montreal, Quebec, Canada, 2016 (n = 44)

Characteristics	Total n= 44 (100%)	Boys n= 28 (64%)	Girls n= 16 (36%)
Age (years)			
mean (SD)	16.3 (1.1)	16.3 (1.1)	16.3 (1.2)
median	16	16	16
IQR	2	2	2.5
Parent education	**n (%)**	**n (%)**	**n (%)**
parents not university educated	17 38.6)	11 (39.3)	6 (37.5)
at least one parent with a university degree	27 (61.4)	17 (60.7)	10 (62.5)
***Total body fat (%)**			
mean (SD)	25.0 (12.4)	19.8 (10.9)	34.2 (9.3)
median	25.0	17.1	30.9
IQR	19.5	15.8	5.9
****Average daily MVPA (minutes)**			
mean (SD)	23.86 (19.8)	28.6 (23.1)	15.5 (7.5)
median	19.7	26.33	15.42
IQR	18.2	21.02	9.82
Missing	11	7	4
Does physical activity	**n (%)**	**n (%)**	**n (%)**
often	22 (50.0)	16 (57.0)	6 (37.5)
sometimes	12 (27.3)	7 (25.0)	5 (31.3)
rarely	5 (11.4)	0 (0.0)	5 (31.3)
never	1 (2.3)	1 (3.7)	0 (0.0)
missing	4 (9.0)	4 (14.3)	0 (0.0)
Surfs the web for entertainment			
often	36 (81.8)	22 (78.6)	14 (87.4)
sometimes	5 (11.4)	4 (14.3)	1 (6.3)
rarely	0	0	0
never	1 (2.3)	0	1 (6.3)
missing	2 (4.5)	2 (7.1)	0
Cares about eating healthy			
often	8 (18.2)	4 (14.3)	4 (25.0)
sometimes	20 (45.5)	11 (39.3)	9 (56.3)
rarely	9 (20.5)	7 (25.0)	2 (12.5)
never	5 (11.3)	4 (14.3)	1 (6.2)
missing	2 (4.5)	2 (7.1)	0 (0.0)

SD, standard deviation; IQR, interquartile range. All variables self-reported unless otherwise indicated.
*derived from DEXA **derived from accelerometers.

Table 3. Social network characteristics, QUALITY Social Network pilot study, Montreal, Quebec, Canada, 2016 (n =44)

Characteristic	Total n = 44			Boys n = 28			Girls n = 16		
	mean	(SD)	range	mean	(SD)	range	Mean	(SD)	range
Social Network Structure:									
Network size	4.7	(2.5)	1-10	4.1	(2.4)	1-10	5.7	(2.6)	1- 9
Network Density	0.9	(0.4)	0 - 1	0.7	(0.4)	0 - 1	0.8	(0.3)	0 -1
Number of Components	1.3	(0.6)	1- 3	1.4	(0.7)	1- 3	1.1	(0.4)	1- 2
Number of Isolates	0.4	(0.8)	0 -3	0.5	(0.9)	0 -3	0.3	(0.6)	0 - 2
Composition of alters:									
Proportion of alters with face-to-face contact	0.89	(0.25)	0-1	0.84	(0.30)	0-1	0.97	(0.06)	0.40-1
Proportion of alters who never do PA	0.09	0.21	0.0-0.8	0.08	0.19	0.0-0.75	0.09	0.24	0.0-0.8
Proportion of alters who rarely do PA	0.25	0.30	0-1	0.22	0.27	0-1	0.31	0.34	0-1
Proportion of alters who sometimes do PA	0.25	0.30	0-1	0.31	0.34	0-1	0.14	0.19	0-0.5
Proportion of alters who often do PA	0.41	0.38	0-1	0.38	0.40	0-1	0.45	0.34	0-1
Proportion of alters who never surfed the web for entertainment	0.09	0.23	0-1	0.09	0.22	0-1	0.09	0.24	0-0.88
Proportion of alters who rarely surfed the web for entertainment	0.05	0.13	0-0.56	0.06	0.12	0-0.5	0.04	0.14	0-0.56
Proportion of alters who sometimes surfed the web for entertainment	0.32	0.35	0-1	0.4	0.35	0-1	0.17	0.30	0-1
Proportion of alters who often surfed the web for entertainment	0.54	0.40	0-1	0.46	0.37	0-1	0.69	0.42	0-1
Proportion of alters who never ate healthy	0.21	0.33	0-1	0.21	0.34	0-1	0.21	0.33	0-1
Proportion of alters who rarely ate healthy	0.24	0.34	0-1	0.24	0.36	0-1	0.24	0.31	0-1
Proportion of alters who sometimes ate healthy	0.37	0.34	0-1	0.33	0.36	0-1	0.41	0.31	0-1

Proportion of alters who often ate healthy	0.19	0.29	0-1	0.22	0.32	0-1	0.14	0.25	0-1
Proportion of alters who never encouraged the ego to be physically active	0.30	0.40	0-1	0.21	0.36	0-1	0.47	0.44	0-1
Proportion of alters who rarely encouraged the ego to be physically active	0.17	0.28	0-1	0.19	0.30	0-1	0.14	0.25	0-1
Proportion of alters who sometimes encouraged the ego to be physically active	0.26	0.34	0-1	0.31	0.35	0-1	0.17	0.29	0-1
Proportion of alters who often encouraged the ego to be physically active	0.27	0.36	0-1	0.29	0.36	0-1	0.23	0.37	0-1
Proportion of negative role models[1]	0.18	(0.30)	0-1	0.17	(0.30)	0-1	0.20	(0.31)	0-1
Proportion positive role models[1]	0.32	(0.30)	0-1	0.34	(0.40)	0-1	0.29	(0.20)	0-0.60
Proportion of cheerleaders[1]	0.19	(0.29)	0-1	0.23	(0.33)	0-1	0.14	(0.19)	0-0.50

Network size, number of friends named by ego; Density, number of existing ties between alters over the number of possible ties; Components, a subgroup of inter-connected alters or isolate; Isolate, alter without any tie to other alters in the network. [1] computed for 43 (missing 1 boy). Ego's alters: +/- 5 years of their age (friends, siblings, cousins, people with whom they do their hobbies). There are 44 egos, and 207 alters in total.

Table 4. Correlation matrix, Spearman correlations, social network characteristics (rhos), QUALITY Social Networks pilot study, Montreal, Quebec, Canada, 2016 (n =44)

	% Body fat z-score	Age	Sex	Parent education	Ego Physical activity	Ego web surfing	Ego eating healthy	Ego MVPA	Positive role model friends	Cheer-leaders P	Negative role model friends	Face-to-face contact	Network size	Density	Components	Isolates
% Body fat z-score	1															
Age	-0.08	1														
Sex	0.07	0.02	1													
Parent education	0.01	0.12	0.02	1												
Ego PA	-0.42	0.06	-0.34	-0.21	1											
Ego web surfing	0.02	<0.01	0.03	-0.03	-0.07	1										
Ego eating healthy	0.01	-0.04	0.23	-0.02	0.01	-0.11	1									
Ego MVPA	-0.31	-0.22	-0.34	0.24	0.02	-0.03	-0.09	1								
Positive role model friend	-0.28	0.31	-0.01	-0.27	0.4	-0.09	0.11	-0.08	1							
Cheer-leaders P	-0.39	0.24	-0.06	-0.28	0.55	-0.1	-0.01	-0.01	0.77	1						
Negative role model friend P	0.24	-0.09	0.02	0.12	-0.1	-0.21	-0.01	0.07	-0.39	-0.24	1					
Face-to-face contact	0.13	-0.17	0.16	-0.15	0.06	-0.24	0.13	0.12	0.05	<0.01	0.13	1				
Network size	0.09	-0.06	0.3	0.03	-0.09	0.05	0.21	-0.14	-0.03	-0.14	0.13	-0.09	1			
Density	0.12	0.11	<0.01	0.18	-0.1	-0.28	-0.04	-0.14	-0.17	-0.08	<0.01	0.02	0.14	1		
Components	-0.14	-0.33	-0.09	-0.14	<0.01	0.21	-0.03	0.23	-0.1	-0.07	0.27	-0.17	-0.08	-0.66	1	
Isolates	-0.2	-0.22	-0.13	-0.11	0.06	0.23	0.03	0.25	-0.05	-0.04	0.1	-0.03	-0.34	-0.77	0.85	1

Table 5. Spearman correlations of study variables with ego adiposity (age- and sex-adjusted total % body fat) Spearman correlations (rhos), QUALITY Social Networks pilot study, Montreal, Quebec, Canada, 2016 (n = 44)

Variable	Total body fat %[1]	Number of Participants	P-value
Egos socio-demographics characteristics:			
Age	-0.08	44	0.59
Sex	0.07	44	0.67
Parent education	0.01	44	0.97
Egos weight-related behaviours:			
Self-reported physical activity frequency	-0.42	40	**0.01**
Self-reported recreational web surfing frequency	0.02	42	0.94
Self-reported eating healthy frequency	0.01	42	0.97
Average daily MVPA[2]	-0.31	33	0.08
Composition of alters:			
Proportion of friends with face-to-face contact	0.13	44	0.26
Proportion of positive role models	-0.28	43	0.07
Proportion of cheerleaders	-0.39	44	**0.01**
Proportion of negative role models	0.24	43	0.12
Social Network Structure:			
Network size	0.09	44	0.56
Density	0.12	42	0.44
Components	-0.14	44	0.38
Isolates	-0.20	44	0.19

[1]body fat % standardized for age and sex.
[2]MVPA: moderate-to-vigorous physical activity (minutes/day)

Table 6. Multilinear regression models predicting adiposity in adolescents by sex in the QUALITY study participants, Montreal, Quebec,Canada, 2016

	Boys		Girls	
	β	**P-value**	**β**	**P-value**
Model 1				
Intercept	24.03	0.37	14.94	0.72
Age (years)	0.50	0.77	1.32	0.58
Network size	-0.66	0.38	-0.27	0.67
Parent education	-5.05	0.20	-2.58	0.81
Cheerleader[1]	-8.48	**<0.01**	0.86	0.79
Model 2				
Intercept	38.93	0.17	31.30	0.43
Age (years)	-0.25	0.89	0.78	0.72
Network size	-0.69	0.35	-0.28	0.78
Parent education	-3.75	0.34	2.14	0.73
Cheerleader[1]	-7.81	**<0.01**	3.52	0.32
Average daily MVPA	-0.13	0.14	-0.79	0.12

β, standardized regression coefficient; p, probability; CI, confidence interval. [1] positive role models who also often or sometimes encouraged the ego to be physically active. [2] Reference: Boys with the lowest tertile of cheerleaders' proportion.

Dictionary

Body fat %: measured by DEXA, standardized by gender and age

Cheerleaders P: Proportion of positive friends who also often or sometimes encouraged the ego to be physically active

Components: Number of components

Density: Network density

Ego eating healthy: ego self-reported of the frequency of eating healthy

Ego PA: ego self-reported of the frequency of physical activity

Ego web surfing: ego self-reported frequency of web surfing for entertainment

Face-to-face contact: the proportion of friends with whom the ego had a face-to-face contact

Isolates: Number of isolates per ego network

MVPA: Average daily moderate-to-vigorous physical activity (min)

Negative role model friends P: Proportion of friends with negative lifestyle behaviour, i.e. rarely or never doing physical activity and eating healthy

Network size: Number of friends

Positive role model friends P: Proportion of friends with positive lifestyle behaviour, i.e. often or sometimes doing physical activity and eating healthy

6. DISCUSSION

The present study explored the relationship between social network characteristics and adiposity in adolescents at risk of obesity. Given that we conducted the present study in the context of a pilot study, we have not attempted to test the hypotheses formally; instead, the broader purpose was to inform a large-scale study and to examine patterns that might generate hypotheses for future analyses in adequately powered studies.

Adolescents with a higher proportion of positive role models — friends who are physically active and who practice healthy eating habits — had lower total percent body fat. Similarly, having a higher proportion of friends with favourable weight-related behaviours and who encouraged egos to be active (i.e. cheerleaders) was strongly inversely correlated with adiposity.

Brechwald and his colleagues in their review of empirical and theoretical research have suggested four possible mechanisms linking adolescent behaviour with that of peers or close friends (86). First, the need for social acceptance can result in the adolescent emulating his peers to match perceived social norms. Second, through the social reinforcement mechanism, a behaviour, when practiced by the adolescent, is approved and reinforced by the peers, hence making the adolescent more prone to behaving similarly. Third, certain behaviours may provide social popularity; and fourth, the behaviour could provide favourable self-identity to the adolescent. In the present study, any of these mechanisms could plausibly underlie the observed correlation between the proportion of cheerleaders in the network and lower percentage body fat. For example, friends involved in a variety of physically active pursuits could encourage other members of the network to become physically active themselves, in the pursuit of social acceptance. Emotionally supportive friends who encourage adolescents to be active reinforce

positive lifestyle behaviours. Additionally, an understanding and encouraging friend will reduce perceptions of the stigma associated with being overweight or obese and can help one move towards empowerment and a healthier lifestyle (95).

We observed sex-specific patterns related to the proportion of supportive friends and adolescent adiposity. Among boys, the proportion of cheerleaders was inversely associated with adiposity, while in girls, the proportion of cheerleaders was positively associated with adiposity. There may be several explanations. First, the sex composition of the friends in the network maybe differs between boys and girls. Not surprisingly, there was evidence of homophily by sex, such that girls were more likely to have female friends in their network and boys more likely to have male friends. Since boys tend to be more involved in physical activities than girls (32, 123), boys' network members were generally more active than the girls' network members. It may also be that girls are more likely to receive or perceive support from family members than from friends (124-127), a relationship we did not examine in the current thesis. These sex-specific patterns may be important to consider when designing lifestyle interventions targeting adolescents peer group, as not all adolescents will benefit equally from activating social relationships.

While perceiving friends to be supportive through role-modelling and encouragement appeared to be associated with lower levels of adiposity, having more physically inactive and non-healthful eating friends (i.e.negative role models) did not appear to be associated with increased adiposity. Hence, the number of 'poor' role models may not matter, as long as there are some favourable influences- at least among boys. This seems to contrast findings reported by De la Haye et al. who, in their one year study, observed that the effect of peers' negative eating behaviours on young people was substantial. In their study of 378 grade eight students, it is

suggested that students' consumption of "junk" foods was predicted by their nominated friends' consumption of junk food, regardless of ego beliefs, even after controlling for pre-existing similarities and other potentially confounding factors (128). In our study, no validated measures of ego's dietary behaviour were available, and it was not possible to explore this question further. We also observed that more frequent interactions with friends was correlated with higher levels of physical activity (129). If these associations hold in well-powered investigations, this suggests that encouraging youth to be active could potentially be facilitated by designing spaces that encourage face to face interactions.

When exploring the social network structures of adolescents in our study, we did not observe correlations between adiposity and structural network measures such as the number of friends or the network size. In contrast, other studies have suggested that having more friends is associated with higher levels of physical activity (130-132). One such study suggested that more friends lead to more opportunities for physical activity participation, such as with team-based structured sports (129, 133). It could be that more nuanced questions about physical activity practices of alters are needed, or that these are measured with too much error. It could also be that the quality of friendships plays a more important role than the number of friends, but this was not measured in the pilot study. Its inclusion is warranted, however, as overweight adolescents with positive friendship qualities have better coping mechanisms, whereas adolescents with negative friendship qualities make them less prone to internal blame attributions compared to average-weight youth (95). Density of the network did not appear to be associated with adiposity in our study. Sawka observed that adolescent boys with highly dense networks were more likely to be highly sedentary compared with boys in sparse networks (134). Other studies showed that higher density social networks were thought to influence health outcomes by

facilitating the rapid transfer of desired health knowledge and attitude, shared resources, and social support through the network (97, 135). The density of the network may be associated with one individual's positive or negative lifestyle behaviours depending on their network members' behaviours. Given that in a highly dense network, information and social norms may spread more rapidly between network members, infusing positive health behaviours in this network may be more efficient than in a sparser network.

The number of network components and isolates were not associated with adiposity. Components for an ego could represent a group of same-aged kin, neighbourhood friends, or school friends; hence, this may allow access to a variety of pursuits. A social network with a lower number of components (and hence higher density) could also be related to increased physical activity if friends are involved in team sports (136) and more positive sports practices (137, 138). Adolescents may be more inclined to get involved in team sports if their friends and their friends' friends are also involved.

Evidence has shown that overweight or obese adolescents are often socially isolated and marginalized (139-141). Moreover, overweight adolescents, especially females, may be less inclined to establish friendships with their peers (142). This isolation could lead to fewer opportunities for physical activities since these are often combined with social events (131). As marginalized overweight adolescents generally feel less confident and less emotionally supported, they may be more prone to adopt unhealthy behaviours such as "*emotional eating*" and inactivity, leading to increased body fat and adverse physical and mental health outcomes (143).

Several studies examining the role of peers in weight-related behaviour among young adults support the viability of involving peers to effect behavioural change (113, 144).

Consequently, it is reasonable to reflect on how adolescents' social networks could be leveraged for obesity prevention. Simple tools for assessing the social networks of adolescents at higher risk for obesity could be developed and shared; these could be helpful to adapt interventions, and potentially to activate the support of key network members. Possible interventions could focus on increasing self-efficacy to provide support and encourage cooperative strategies, notably in clinical practice, especially in primary health care, where physicians play an active role in obesity prevention, working side by side with families and adolescents. Long-term relationships are established as health care physicians may follow these adolescents throughout their lives.

This pilot study used a state-of-the-art technology for assessing adiposity and MVPA. We examined a range of social network measures and characteristics in relation to obesity in vulnerable adolescents, providing novel and original insight into an important public health problem. Access was provided to robust research infrastructure, including a multidisciplinary team of experienced researchers, research assistants, research coordinators, and clinicians.

Though limited by a more exploratory perspective, the study is an important step towards a larger scale study, and findings are suggestive of relationships that are worth examining in greater depth in a larger scale undertaking. Nevertheless, the current thesis is based on a relatively small sample, and interpretations are made with caution. In small sample pilot studies, not statistically significant results are inconclusive, since "*no evidence of effect is not evidence of no effect*" (145) as cited in Thabane L, et al. article (146). Nevertheless, despite its limited sample size, we were able to discern some patterns in the relationship between perceived behaviours in social network and weight status; these warrant further investigation. Most of the data were based on self-reported values, contributing to likely misclassification. In particular, questions about their friends' physical and eating behaviours could be affected by recall bias.

Arguably, the perception of their behaviours and their support may be more relevant than the actual behaviours, as evidence shows that it is perceived and not received social support that matters most to health (147). Nevertheless, lack of confirmation of study participants' perceptions of their friends' health behaviours is a notable limitation.

7. CONCLUSION

Overall, in the context of this pilot study, our observations suggest that the social network may be implicated in the weight status of adolescents. Notably, supportive friends with favourable obesity-related behaviours may be protective of adiposity in boys. Given the many adverse consequences of obesity in childhood and adulthood, and given that children with obesity tend to maintain their excess weight through adolescence and young adulthood (148, 149), novel approaches to enhance prevention and treatment efforts are needed throughout the life course. As children progress to adolescence and start to develop more autonomy with respect to mobility and to selection of friends, this period warrants greater attention in order to better understand how to provide optimally supportive physical and social environments.

8. FIGURES AND SUPPLEMENTARY TABLES

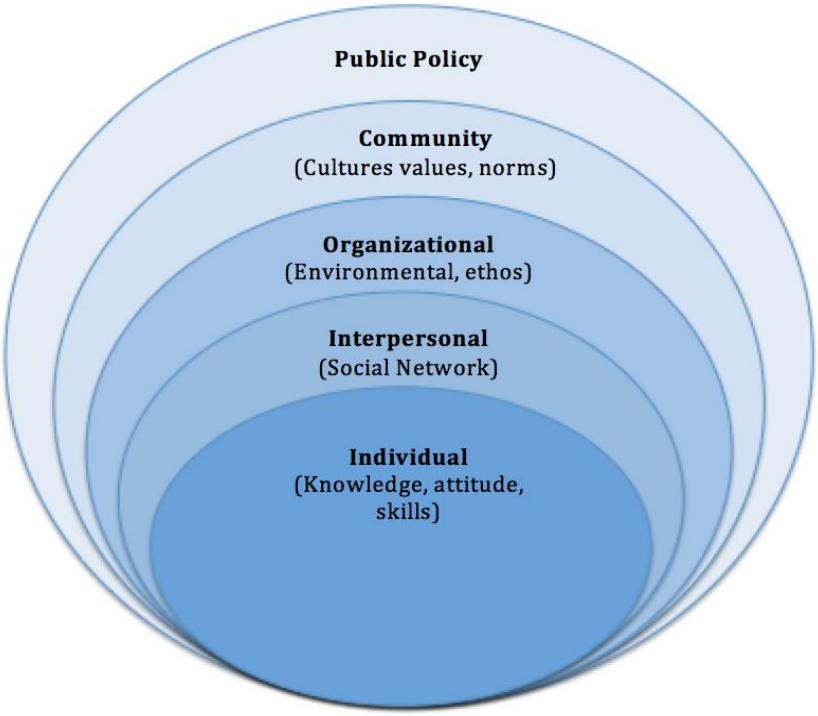

Figure 1. Illustration of Socio-ecological Model

source: Adapted from the Centers for Disease Control and Prevention (CDC), The Social Ecological Model: A Framework for Prevention, http://www.cdc.gov/violenceprevention/overview/social-ecologicalmodel.html (retrieved November 2, 2018).

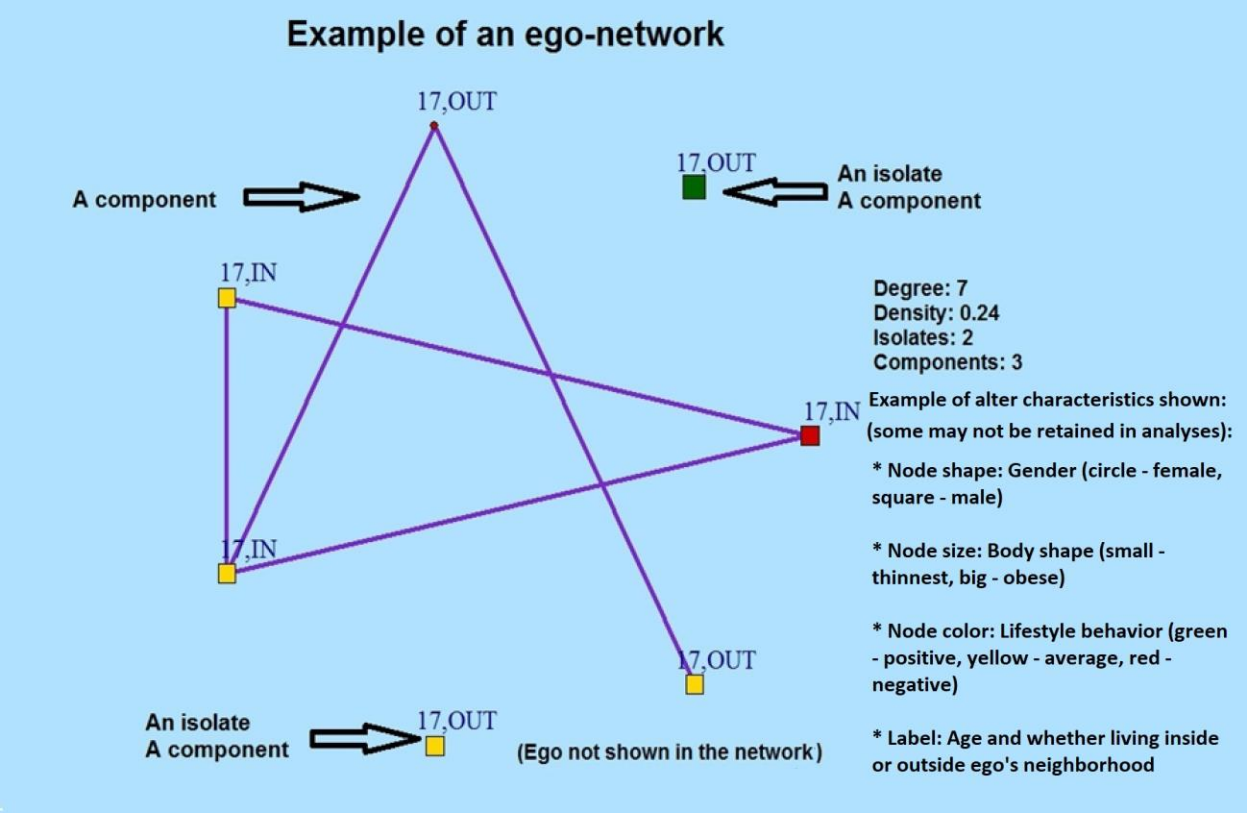

Figure 2 Illustration of Ego-centric Social Network

Glossary of terms
Ego: The adolescent participating in this study
Alter: Individual that an ego nominated as an important and close person (friend)
Network size: Number of friends in a social network.
Density: Number of existing ties between alters over the number of possible ties
Components: Subgroup of inter-connected alters or isolates
Isolate: Alter without any tie to other alters in the network
Homophily: when an individual form a bond (tie) with someone with a similar trait
Positive role model friends: Friends with positive lifestyle behaviour, i.e. often or sometimes participating in physical activities and eating healthy food
Negative role model friends: Friends with negative lifestyle behaviour, i.e. rarely or never participating in physical activities and eating unhealthy food
Cheerleaders: Positive role models who also often or sometimes encouraged the ego to be physically active

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10. APPENDICES

Appendix I: Information and Consent Form

For Parents and Child

Study Title:

Familial Study on the Prevention of Cardiovascular Disease and type 2 Diabetes in Children and Adolescents

Investigators:

Principal Investigator: Marie Lambert, M.D.

Co-Principal Investigators: Jennifer O'Loughlin, Ph.D., Angelo Tremblay, Ph.D.

Co-Investigators: Katherine Gray-Donald, Ph.D., James A Hanley, Ph.D., Émile Levy, Ph.D., Gilles Paradis, M.D., Paul Poirier, M.D.

Collaborators: Christian Caron, DMD, Edgard Delvin, Ph.D., Josée Dubois, m.d., Lise Gauvin Ph.D., Jennifer McGrath, Ph.D., Grant Mitchell, m.d., Lyne Mongeau, Dt.P., Belinda Farias Nicolau, Ph.D., Judith Simoneau-Roy, m.d., Daniel Sinnett, Ph.D., Catherine Sabiston, Ph.D., Eric Loucks, Ph.D., Laurent Legault, m.d., Tracie Barnett, Ph.D., Vicky Drapeau, Ph.D.

Source of Funding:

This project is funded by the Canadian Institutes of Health Research (CIHR) and by the Canadian Heart and Stroke Foundation.

You have been asked to participate because one or more members of your family are at risk for cardiovascular disease or type 2 diabetes. Please take time to carefully consider whether or not you would like to participate. It is important that you read this document carefully, and then address any questions you have to the principal investigator or other members of the research team.

Why is this study being done?

Cardiovascular disease and type 2 diabetes are among the most important health problems in Canada today. Risk factors for cardiovascular disease and type 2 diabetes are detectable in children, and atherosclerosis (the ageing process of arteries that leads to cardiovascular disease) begins at a young age.

Cardiovascular disease and type 2 diabetes have several risk factors in common including overweight or obesity, hypertension (high blood pressure), abnormal blood lipids (fats), and glucose (sugar) intolerance. We often observe the clustering of these risk factors within the same family. When several of these risk factors are present in a single individual, this person is said to have an insulin resistance syndrome (also called the metabolic syndrome). The insulin resistance syndrome can be found in adults, children and adolescents.

The objectives of this study are: 1) to study the natural history of the insulin resistance syndrome in children and adolescents; 2) to determine if certain behaviours, physical signs, biochemical anomalies, or genetic characteristics predict the onset of the insulin resistance syndrome; and 3) to examine the relationship between the insulin resistance syndrome, its components and the early signs of atherosclerosis (hardening of the arteries). We believe that better understanding the natural history of the insulin resistance syndrome, its early indicators and its metabolic consequences will result in better prevention. To meet these objectives, studies lasting several years are necessary.

What will we have to do? What requirements will we have to meet?

This is a familial study that requires participation by two (2) biological parents and one (1) child aged 8-10 years at the time of study entry. This study necessitates that your family spend one day

at the Clinical Research Unit at Ste-Justine Hospital in Montreal. This evaluation visit will be repeated every two years for 8 to 10 years until your child reaches 18 years of age. You must arrive at the hospital early in the morning (around 7:00 am), after having fasted since 8:00 PM the previous evening. During the visit, we will ask each of you to complete a 20-30minute questionnaire on your health, lifestyle, and family history. Postal codes of your home and of the school that the child attends will be noted. Because the research team is also interested in how environments influence lifestyles, all schools and neighbourhoods of participating families will be visited in order to observe specific opportunities for physical activity and healthy eating. Names of study participants will remain anonymous, and will not be revealed either to school personnel or to research assistants collecting data. We will measure the weight, height, skinfold thicknesses, waist circumference, hip circumference, and blood pressure of each participating family member. We will evaluate the sexual maturity (puberty) of the child by ascertaining his/her Tanner stage. We will ask the child for a fasting urine sample. We will draw 10mL (2 teaspoons) of blood from each participating family member to measure glucose, insulin, and lipids levels in plasma (liquid portion of blood). Plasma will be stored for future tests related to overweight, obesity, cardiovascular disease or type 2 diabetes. Blood cells will be used to extract DNA which contains a person's genetic information*. Before drawing the blood sample, we will apply an anesthetic (numbing) cream on the skin to minimize discomfort associated with this procedure. Following the initial blood draw, the child will undergo a metabolic challenge to measure insulin sensitivity. For this metabolic challenge, the child will be asked to drink a sugared solution, after which six (6) blood samples of 5mL (1 teaspoon) will be drawn at timed intervals to measure insulin and glucose levels in the blood. Plasma will be stored. All blood draws from the child will be done through the same flexible Teflon catheter inserted into an arm

vein; therefore, there will only be one needle insertion for all blood samples drawn from the child. During the metabolic challenge, the child's heart rate will be recorded using a Holter instrument.

* DNA and plasma preservation

As mentioned above, blood samples will be used to collect white blood cells, from which DNA will be extracted. DNA is a molecule containing all hereditary genetic information that directs the activity of all cells in our bodies. DNA provides instructions that determine a person's hereditable characteristics, such as eye colour and blood group. In this study, DNA will be used only to study genes associated with the development of obesity and its associated diseases (cardiovascular diseases and type 2 diabetes). Samples of the DNA and plasma (in coded form) from each family member will be preserved for 20 years in our research laboratory at Ste-Justine Hospital under the supervision of Marie Lambert, m.d., the principal investigator of this study. You may request the destruction of your DNA or plasma samples at any time during this 20-year period. Some of your DNA or plasma samples may be transmitted in coded form to other investigators associated with this study, always with the objective of studying genes or biological markers associated with obesity and its associated diseases (cardiovascular disease and type 2 diabetes). A new consent will be required for your coded DNA to be used in other research or for it to be sent to other investigators not associated with this study. Please note that it will be impossible for these investigators to know your identity.

A meal will be served for the entire family, once the blood samples have been drawn.

After lunch, the child will undergo a 15-20 minute dental examination by a dentist to examine tooth and gum health. Samples of dental plaque and saliva will be collected to examine saliva

composition and assess the presence of micro-organisms associated with dental caries and periodontal disease (e.g. gingivitis).

After the dental exam, the child will undergo three (3) tests. First, a 15-30 minute test will be done to measure the amount of fat, muscle, and bone in his/her body. This test is called "*dual-energy X-ray absorptiometry (DEXA)*," and it involves whole-body examination with low-dose X-rays. Exposure to X-rays is minimal, approximately 0.94 millirems, which is less than one day of exposure to sunlight.

The second test is a 15-minute ultrasound of the carotid arteries in the neck. It is a painless and safe examination in which an image of the carotid artery is produced by applying a sensor to the neck. The presence of atherosclerosis is ascertained from the image produced.

The third test evaluates physical fitness. The child's step (stride) length will be measured by asking him/her to walk along a predetermined path. His/her posture will be evaluated by asking him/her to stand on two feet, then on one foot with his/her eyes open, and then on two feet with eyes closed. The final evaluation is called the VO_2max. This evaluation is done on a bicycle and requires that the child pedal with progressively increasing effort. While the child is pedalling, his/her heart rate, blood pressure, and expired $C0_2$ (carbon dioxide) concentration (by mouth) will be recorded. This test allows us to calculate the amount of oxygen used during maximal physical exertion, which is a measure of physical fitness.

After these three (3) tests, the family will have completed all evaluations required during the visit to the Clinical Research Unit. However, your help is still be needed for several at home evaluations. In addition to the child's physical fitness, we would like to measure his/her participation in physical activity. To do this, the child will be asked to wear an accelerometer, a small (1 inch x 1 inch), a light instrument that measures movement. This instrument will be

attached to his/her belt, over or under clothing, during the day for the week following the hospital visit. The accelerometer should be returned by mail in the stamped addressed envelope provided. In addition, an interviewer will telephone the child on two occasions during the year following the hospital visit, to complete a 10-minute questionnaire on participation in physical activity during the preceding week.

We also ask that the child provide 5 saliva samples on one day during the weekend following the hospital visit, by chewing on a small piece of cotton at five designated times. These samples should be mailed to us with the accelerometer.

Finally, our evaluation would not be complete if we did not take into account the child's dietary habits. To do so, we will telephone your child 3 times during the month following the hospital visit and conduct a telephone interview lasting approximately 20 minutes to evaluate the child's diet. During the interview, we will ask the child what he/she ate for meals and snacks during the day preceding the telephone call.

The next page shows a schematic representation of the evaluation schedule.

Schedule of Evaluations

7:00 a.m.	Welcome, information on the day's activities, and signing of the consent form	
7:15 a.m.	Local anesthetic cream application for parents and child	
7:30 a.m.	Measurement of weight, height, skinfold thicknesses, and waist and hip circumferences, and Tanner (puberty) staging of the child Measurement of weight and height of parents	
8:00 a.m.	<u>Parents</u> Fasting blood draw Breakfast Questionnaires Blood pressure measurement Skinfold thicknesses and waist circumference measurements	<u>Child</u> Fasting blood draw Metabolic challenge and heart rate evaluation (Holter) Explanation of the 7-day recall of physical activity and the 24-hour food recall to be done by telephone after the hospital visit Explanation of the accelerometer that will be worn during the week following the visit
12:00 p.m.	Lunch	
1:00 p.m.	Blood pressure measurement for the child	
1:15 p.m.	Dental examination for the child	
1:30 p.m.	Child questionnaire	
2:00 p.m.	Body composition evaluation (DEXA) for child	
2:30 p.m.	Carotid ultrasound for child	
3:00 p.m.	Physical fitness evaluation (step length, posture, VO_2max)	
4:00 p.m.	End of the visit	

At home

- Accelerometer for 7 days after the visit
- Saliva samples
- 24-hour food recall (3 times in the month after the hospital visit)
- 7-day physical activity recall (twice that year)

What might prevent our family from participating in this study?

A child cannot participate in this study if he/she:

- is known to have type 1 or type 2 diabetes;
- is taking steroids, β-blockers or thiazides;
- is on a strict calorie-restricted diet (< 600 Kcal/day);
- was hospitalized in the month preceding study entry for a serious illness (e.g. osteomyelitis);
- is known to have a serious chronic disease (e.g. cystic fibrosis, inflammatory bowel disease, renal insufficiency);
- has intellectual or psychological problems that would prevent him/her from meeting the study requirements.

A parent cannot participate if he/she is known to have type 1 diabetes or a serious chronic illness (e.g. cancer, inflammatory bowel disease, renal insufficiency) or for personal reasons.

What are the inconveniences, possible side effects, or risks that may occur during the study?

Because the evaluations are done on a weekday, the child will be absent from school, and the parents will be absent from work for one day.

Risks associated with participation in this study are few and minimal. Anthropometric measurements of weight, height, waist and hip circumferences and skinfold thicknesses carry no risk. Repeated blood pressure measurements may cause some discomfort due to the blood pressure cuff on the arm. Blood draws will be performed by a qualified nurse, but can cause bruising or discomfort at the site of needle insertion, or fainting. To minimize discomfort associated with needle insertion, you will be offered a local anesthetic cream that is applied to the skin, that produces local anesthesia (numbing). Allergy to this cream is rare but possible. The child may feel discomfort associated with wearing the catheter. Concerning the dental exam, the child may be nervous or feel discomfort during the examination. The test used to determine VO_2max (physical fitness) can cause discomfort in children, during, after, or in the days

following the test. There is no known risk associated with the DEXA measurement of body composition or the carotid ultrasound.

What are the benefits for our family from participating in this study?

If you so choose, we will send you the results on lipids and glucose from your blood tests, with the interpretation of the results (please note that we will not send you the results of any genetic analyses). You can also obtain test results with expert interpretation for the physical fitness and body composition evaluations of your child. It is possible that there will be no immediate benefits for you or your family from participating in this study. However, the entire community will benefit if we are able to develop better interventions strategies to prevent cardiovascular disease and type 2 diabetes based on the results of this study.

How many families will participate in the study?

Over 800 Québec families will participate in this study.

Who will have access to my family's results and know that we participated in this study?

All information about your family obtained in this study is completely confidential, *except when you yourself provide authorization for the release of information or when the law makes an exception*. All biological samples and other information will be coded using a unique identification number.

Data from this study will be kept in locked storage at Ste-Justine Hospital for a period of 20 years. Only the study investigators and staff will have access to the files. Biological samples (plasma, urine, DNA) will be preserved for a period of 20 years at Ste-Justine Hospital. If you

wish to have your samples destroyed during this 20-year period, you must contact the study coordinator.

To ensure proper conduct of this study, it is possible that representatives from the Institutional Review Board or the funding agencies may consult the data.

Results from this study will be published and communicated during scientific conferences, but no information that would enable the identification of your family will be disclosed.

Is there compensation for the expenses and inconveniences of participating in this study?

Your family will receive $25 per visit to the Clinical Research Unit at Ste-Justine Hospital (i.e. every two years) to defray expenses incurred and inconveniences experienced as a result of participating in this study.

What are the study investigators' responsibilities?

If anyone in your family experiences any side-effects to the procedures used to collect data, he/she will receive all the care required by his/her health status, covered under the Québec Health Insurance Plan and the hospitalization insurance plan of Québec or by your private drug insurance plan.

Your family will be made aware of other care options and/or new discoveries concerning the potential risks of this study occur that may influence your decision to continue to participate in this study.

By signing this consent form, you do not renounce to any of your legal rights or your child's legal rights. Moreover, the investigators remain responsible both legally and professionally in the event of a situation that would cause harm to your family.

Can we refuse to participate in this study or withdraw consent to participate?

It is understood that your family will participate in this study of its own free will. You may refuse to participate or choose to withdraw from the study at any time during the next 10 years without any prejudice or loss of privileges to which you are entitled.

Withdrawal of your family from the study may be required without your consent if the physician responsible for the study decides that you no longer meet the study requirements.

Who can we contact in case of difficulties or answer questions?

For more information concerning this study, please contact Dr. Marie Lambert, the principal investigator, at Ste-Justine Hospital (514) 345-4727, or Mr. Hugues Charron, the study coordinator, at (514) 345-7751 or, toll-free, at 1-877-326-8596.

For any information concerning the rights of your family as study participants, you can contact the clientèle adviser of Ste-Justine Hospital at 514-345-4749.

Consent and Assent

The nature and sequence of the Familial Study on the Prevention of Cardiovascular Disease and type 2 Diabetes in Children and Adolescents was explained to us. We read the information and consent form, and we were given a copy of the form. We had the opportunity to ask questions that were adequately answered. After careful consideration, we agree to participate in this study, and we also agree that our child can participate in this study.

Our family	wishes	☐	does not wish	☐	to be sent test results (weight, height, blood pressure, blood lipids and glucose, physical fitness evaluation, body composition).
Our family	wishes	☐	does not wish	☐	to be contacted again in the future by the investigators of this study to obtain consent for other research to be conducted using our coded DNA samples, or for our coded DNA samples to be sent to other investigators not associated with this study.

I understand what is required of me if I participate in this study. I asked all the questions that I had, and the person responsible for the study answered them. I agree to participate in this study.

_____

Child's Name (Please print.)

_____ _____

Child's Assent (Signature) Date

Assent of the child able to understand but unable to write Yes ☐ No ☐

_____

Mother's Name (Please print.)

_____ _____

Mother's Consent (Signature) Date

_____

Father's Name (Please print.)

_____ _____

Father's Consent (Signature) Date

Investigator's and Designated Representative's Agreements

I explained to the participant and to the parent/legal guardian all relevant aspects of the research, and I answered their questions. I explained that their participation in the research project is free and voluntary and that their participation can be ceased anytime

Name of designated representative that obtained consent (Please print)	Signature	Date

The study must be explained to the participant and to the parent/legal guardian as well as the study procedures. A member of the research team must answer their questions and must explain that their participation in the research project is free and voluntary. The research team commits itself to respect what was agreed in this informed consent form.

Name of investigator (Please print)	Signature	Date

Appendix II : Questionnaire for the pilot SNA study

QUESTIONNAIRE RÉSEAU SOCIAL

NIF du participant
Date à laquelle le questionnaire a été rempli

DIRECTIVES: Ce questionnaire porte sur les personnes qui sont importantes dans ta vie et sur ta relation avec ces personnes.

1. Avec qui as-tu discuté de choses qui te sont importantes dans la dernière année? Tu peux identifier jusqu'à 10 personnes.

	Nom complet	Indique si cette personne est un membre de ta famille (par exemple, mère, frère, cousin)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

2. S’il te plaît, décris chacune de ces personnes:

Nom	Cette personne est : 1: un garçon 2: une fille	Quel âge a cette personne? [entrez l’âge] -ou- 99: je ne sais pas	Quelle est son origine ethnique? 1: Blanche 2: Chinoise 3: Sud-Asiatique (Inde, Pakistan, Sri Lanka) 4: Noire 5: Amérique latine 6: Asie du sud-est (Cambodge, Indonésie, Vietnam) 7: Arabe 8: Ouest-Asiatique (Afghanistan, Iran) 9: Autre (spécifier) 99: Je ne sais pas	Si 9: Autre, spéficier
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

3. Depuis combien de temps connais-tu cette personne? Mets in « X » dans la case qui correspond le mieux

Nom	Moins d’un an	1 à 2 ans	3 à 5 ans	Plus de 5 ans	Je ne sais pas
1.	□	□	□	□	□
2.	□	□	□	□	□

3.	□	□	□	□	□
4.	□	□	□	□	□
5.	□	□	□	□	□
6.	□	□	□	□	□
7.	□	□	□	□	□
8.	□	□	□	□	□
9.	□	□	□	□	□
10.	□	□	□	□	□

4. Sur une échelle de 1 à 3, où 1= « pas vraiment importante », 2=« assez importante », et 3= « très importante », à quel point est-ce que cette personne est importante dans ta vie?

Mets in « X » dans la case qui correspond le mieux

Nom	Réponse			
	1 = pas vraiment importante	2 = assez importante	3 = très importante	Je ne sais pas
1.	□	□	□	□
2.	□	□	□	□
3.	□	□	□	□
4.	□	□	□	□
5.	□	□	□	□
6.	□	□	□	□
7.	□	□	□	□
8.	□	□	□	□
9.	□	□	□	□
10.	□	□	□	□

5. Sur une échelle de 1 à 3, où 1=« pas vraiment proche », 2= « assez proche» et 3= « très proche», à quel point te sens-tu proche de cette personne?

Mets in « X » dans la case qui correspond le mieux :

Nom	Réponse			
	1 = pas vraiment proche	2 = assez proche	3 = très proche	Je ne sais pas
1.	□	□	□	□
2.	□	□	□	□
3.	□	□	□	□
4.	□	□	□	□
5.	□	□	□	□
6.	□	□	□	□
7.	□	□	□	□
8.	□	□	□	□
9.	□	□	□	□
10.	□	□	□	□

6. Quelle est la fréquence à laquelle tu es en contact avec cette personne? (face à face, courriel, messages textes, téléphone, Facebook, etc). Mets in « X » dans la case qui correspond le mieux :

Nom	Plusieurs fois par jour	Environ 1 fois par jour	Plusieurs fois par semaine	Plusieurs fois par mois	Environ 1 fois par mois	Plusieurs fois par an	Moins d'une fois par an	Je ne sais pas
1.	□	□	□	□	□	□	□	□
2.	□	□	□	□	□	□	□	□
3.	□	□	□	□	□	□	□	□
4.	□	□	□	□	□	□	□	□
5.	□	□	□	□	□	□	□	□
6.	□	□	□	□	□	□	□	□
7.	□	□	□	□	□	□	□	□

8.	□	□	□	□	□	□	□	□
9.	□	□	□	□	□	□	□	□
10.	□	□	□	□	□	□	□	□

7. Quel(s) moyen(s) utilises-tu pour garder contact avec cette personne? Choisis toutes les options qui s'appliquent.

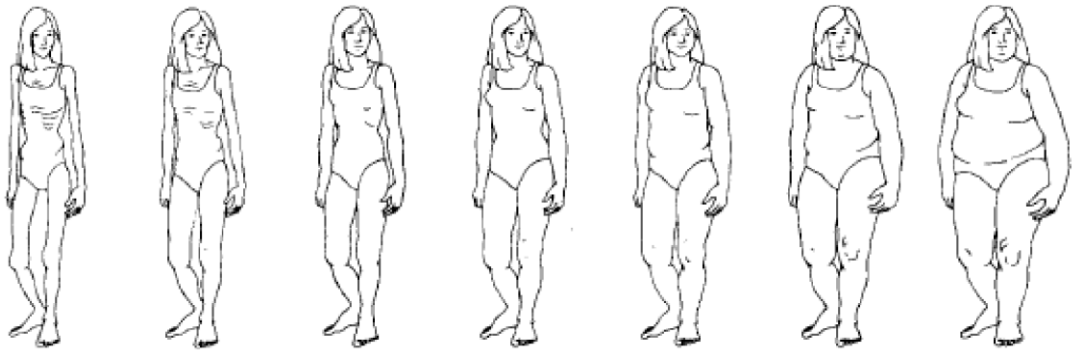
Nom	Face à face	Parle au téléphone	Courriel	Messages textes	Réseaux sociaux (Facebook, Twitter, etc.)	Appels vidéos (Skype, FaceTime, etc.)	Autre (spécifier)	Je ne sais pas
1.	□	□	□	□	□	□	□	□
2.	□	□	□	□	□	□	□	□
3.	□	□	□	□	□	□	□	□
4.	□	□	□	□	□	□	□	□
5.	□	□	□	□	□	□	□	□
6.	□	□	□	□	□	□	□	□
7.	□	□	□	□	□	□	□	□
8.	□	□	□	□	□	□	□	□
9.	□	□	□	□	□	□	□	□
10.	□	□	□	□	□	□	□	□

8. Où est située cette personne (où réside-t-elle)? Mets in « X » dans la case qui correspond le mieux :

Nom	Chez moi	Dans mon quartier	À l'extérieur de mon quartier	Je ne sais pas
1.	□	□	□	□
2.	□	□	□	□
3.	□	□	□	□
4.	□	□	□	□
5.	□	□	□	□
6.	□	□	□	□
7.	□	□	□	□
8.	□	□	□	□
9.	□	□	□	□
10.	□	□	□	□

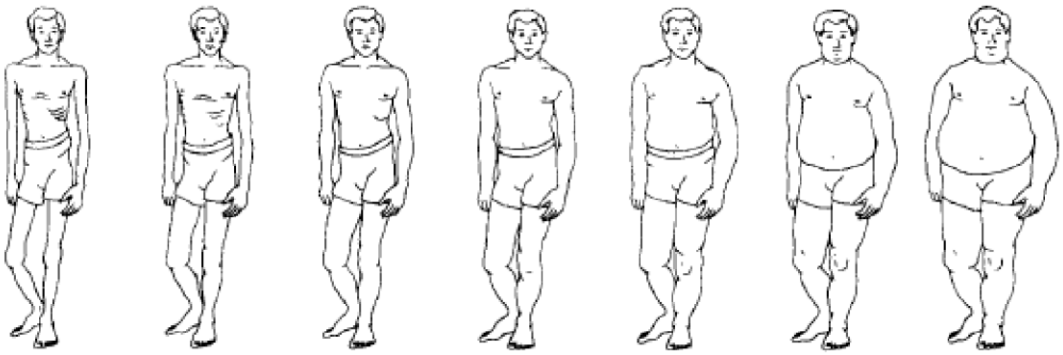
9. Parmi les silhouettes ci-dessous, indique, par le numéro correspondant, celle qui ressemble le plus à chacune des personnes que tu as identifiées, en commençant par toi-même.

Filles



1 2 3 4 5 6 7

Garçons



1 2 3 4 5 6 7

Nom	Silhouette (échelle 1 à 7)	Je ne sais pas
Toi-même		
Nom 1.		
Nom 2.		
Nom 3.		
Nom 4.		
Nom 5.		
Nom 6.		
Nom 7.		
Nom 8.		
Nom 9.		
Nom 10.		

10. Où/Comment est-ce que tu interagis avec cette personne? Coche tous les choix qui s'appliquent:

Nom	À la maison	À l'école	Au travail	Lors d'activités de loisir ou sorties sociales	Medias sociaux (téléphone, messages textes, réseaux sociaux, courriels, etc.)
1.	□	□	□	□	□
2.	□	□	□	□	□
3.	□	□	□	□	□
4.	□	□	□	□	□
5.	□	□	□	□	□
6.	□	□	□	□	□
7.	□	□	□	□	□
8.	□	□	□	□	□
9.	□	□	□	□	□
10.	□	□	□	□	□

11. Pour chacune des personnes que tu as identifié, indique la fréquence à laquelle vous pratiquez des activités physiques ensemble pour 30 minutes ou plus.

Mets in « X » dans la case qui correspond le mieux :

Nom	Jamais	1-2 fois par mois	1 fois par semaine	Plusieurs fois par semaine	Tous les jours
1.	□	□	□	□	□
2.	□	□	□	□	□
3.	□	□	□	□	□
4.	□	□	□	□	□

5.	□	□	□	□	□
6.	□	□	□	□	□
7.	□	□	□	□	□
8.	□	□	□	□	□
9.	□	□	□	□	□
10.	□	□	□	□	□

12. Sur une échelle de 1 à 4, 1 étant « souvent » et 4 étant « jamais », à quel point te sens-tu encouragé(e) par cette personne dans tes efforts pour participer à, ou t'engager dans, des activités physiques?

Mets in « X » dans la case qui correspond le mieux :

Nom	1 = Souvent	2 = Parfois	3= Rarement	4 = Jamais
1.	□	□	□	□
2.	□	□	□	□
3.	□	□	□	□
4.	□	□	□	□
5.	□	□	□	□
6.	□	□	□	□
7.	□	□	□	□
8.	□	□	□	□
9.	□	□	□	□
10.	□	□	□	□

13. Indique, à ta connaissance, la fréquence à laquelle chacune de ces personnes, en commençant par toi-même, entreprennent les activités suivantes : Faire de l'exercice à une intensité suffisante pour transpirer.

Mets in « X » dans la case qui correspond le mieux :

Nom	1 = Souvent	2 = Parfois	3= Rarement	4 = Jamais	9 = Je ne sais pas
Toi-même	□	□	□	□	□
1.	□	□	□	□	□
2.	□	□	□	□	□
3.	□	□	□	□	□
4.	□	□	□	□	□
5.	□	□	□	□	□
6.	□	□	□	□	□
7.	□	□	□	□	□
8.	□	□	□	□	□
9.	□	□	□	□	□
10.	□	□	□	□	□

14. Indique, à ta connaissance, la fréquence à laquelle chacune de ces personnes, en commençant par toi-même, entreprennent les activités suivantes : Passer du temps sur Internet pour le plaisir, regarder la télévision, jouer à des jeux vidéo.

Mets in « X » dans la case qui correspond le mieux

Nom	1 = Souvent	2 = Parfois	3= Rarement	4 = Jamais	9 = Je ne sais pas
Toi-même	□	□	□	□	□
1.	□	□	□	□	□
2.	□	□	□	□	□
3.	□	□	□	□	□

4.	□	□	□	□	□
5.	□	□	□	□	□
6.	□	□	□	□	□
7.	□	□	□	□	□
8.	□	□	□	□	□
9.	□	□	□	□	□
10.	□	□	□	□	□

15. Indique, à ta connaissance, la fréquence à laquelle chacune de ces personnes, en commençant par toi-même, entreprennent les activités suivantes : Faire attention à ce que tu/elle mange (par exemple, éviter la malbouffe, les boissons gazeuses, les sucreries, etc.)

Mets in « X » dans la case qui correspond le mieux

Nom	1 = Souvent	2 = Parfois	3= Rarement	4 = Jamais	9 = Je ne sais pas
Toi-même	□	□	□	□	□
1.	□	□	□	□	□
2.	□	□	□	□	□
3.	□	□	□	□	□
4.	□	□	□	□	□
5.	□	□	□	□	□
6.	□	□	□	□	□
7.	□	□	□	□	□
8.	□	□	□	□	□
9.	□	□	□	□	□
10.	□	□	□	□	□

16. Indique, à ta connaissance, la fréquence à laquelle chacune de ces personnes, en commençant par toi-même, entreprennent les activités suivantes : Entreprendre une diète dans le but de perdre du poids.

Mets in « X » dans la case qui correspond le mieux

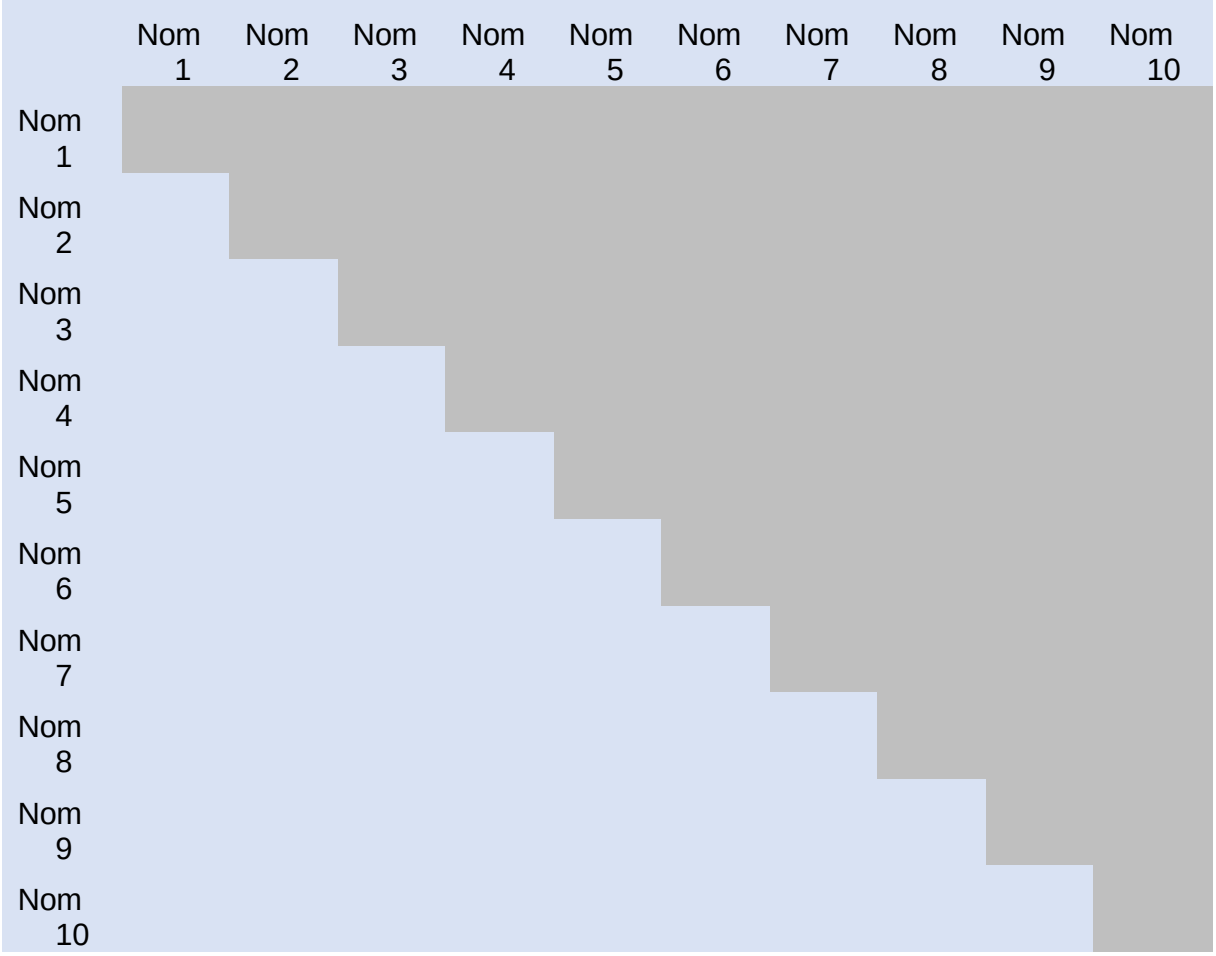
Nom	1 = Souvent	2 = Parfois	3= Rarement	4 = Jamais	9 = Je ne sais pas
Toi-même	□	□	□	□	□
1.	□	□	□	□	□
2.	□	□	□	□	□
3.	□	□	□	□	□
4.	□	□	□	□	□
5.	□	□	□	□	□
6.	□	□	□	□	□
7.	□	□	□	□	□
8.	□	□	□	□	□
9.	□	□	□	□	□
10.	□	□	□	□	□

17. Indique, dans les cases en blanc, à quel point chacune des personnes identifiées se connaissent, selon l'échelle suivante :

0: ne se connaissent pas

1: se connaissent un peu

2: se connaissent bien ou très bien


Nom 1
Nom 2
Nom 3
Nom 4
Nom 5
Nom 6
Nom 7
Nom 8
Nom 9
Nom 10
Nom 1
Nom 2
Nom 3
Nom 4
Nom 5
Nom 6
Nom 7
Nom 8
Nom 9
Nom 10