A LONGITUDINAL EXAMINATION OF THE INTERRELATIONSHIP OF MULTIPLE HEALTH BEHAVIOURS

by

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Abstract

Background: Evaluating the interrelationship of health behaviours could assist in the development of effective public health interventions. Furthermore, the ability to identify cognitive mediating mechanisms that may influence multiple behavioural change requires further evaluation.

Purpose: The objectives of this nationally representative multi-wave longitudinal analysis were: (1) to evaluate co-variation among health behaviours; specifically alcohol consumption, leisure-time physical activity, and smoking, and (2) to examine whether mastery acts as a mediating cognitive mechanism that facilitates multiple health behaviour change.

Methods: Secondary data analysis was conducted on the first seven cycles of the Canadian National Population Health Survey. Data collection began in 1994/1995 and has continued biennially to 2006/2007. This longitudinal sample consisted of 15,167 Canadians 12 years of age or older. Alcohol consumption, leisure-time physical activity,

and smoking were assessed as continuous variables. Parallel process growth curve models were used to analyze co-variation between health behaviours as well as to evaluate the potential mediating effects of perceived mastery.

Results: An increase in leisure-time physical activity was associated with a greater reduction in tobacco use, while a flatter positive trajectory in alcohol consumption was associated with a steeper decline in tobacco use. Co-variation between alcohol consumption and leisure-time physical activity did not reach statistical significance. For the most part, mastery was unsuccessful in mediating the interrelationship of multiple behavioural changes.

Conclusions: Health behaviours are not independent, but rather interrelated. Although one could argue that the estimated magnitude of such behavioural changes were quite small, modest and attainable behavioural changes at the population level can have considerable effects on the morbidity, mortality, and health care costs. In order to optimize limited prevention resources, these results suggest that population level intervention efforts targeting multiple modifiable behavioural risk factors may not need to occur simultaneously.

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List of Abbreviations

BMI	Body Mass Index
CFI	Comparative Fit Index
CI	Confidence Interval
cov	Covariance
HMO	Health Maintenance Organization
KCALS	Kilocalories
Kcal/kg/day	Kilocalories/Kilograms/Day
Kg	Kilograms
M	Metres
MESH	Medical Subject Heading
NPHS	National Population Health Survey
PSAE	Participation in Sports, Athletics or Exercising
r	Correlation
rANOVA	Repeated-Measures Analysis of Variance
RDC	Research Data Centres
rMANOVA	Multivariate Repeated-Measures Analysis of Variance
RMSEA	Root Mean Square Error Approximation
SRMR	Standardized Root Mean Squared Residual
SSHRC	Social Sciences and Humanities Research Council
X^2	Chi-Square Goodness-of-Fit Statistic

Glossary of Terms

Clustering:

Refers to a grouping of two or more health behaviours that is "more prevalent than can be expected on the basis of the prevalence of separate risk factors" (Schuit, van Loon, Tijhuis, & Ocke, 2002, pg. 219).

Co-variation:

Refers to "taking effective action on one behaviour increases the odds of taking effective action on a second behaviour" (J. O. Prochaska, 2008, pg. 282).

Gateway Behaviour:

Refers to "a behaviour that, when intervened upon, has a positive influence on other behaviour changes" (Nigg, Allegrante, & Ory, 2002, pg.676).

Health Behaviour:

Refers to "actions in which individuals engage that influence health. The impact can be negative, as with tobacco and other drug use and risky sexual behaviours, or positive, as with physical activity, fruit and vegetable consumption, and the wearing of helmets or seatbelts" (J. J. Prochaska, Spring, & Nigg, 2008, pg. 183).

Intentions:

Refers to "indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour" (Ajzen, 1991, pg. 181).

Leisure:

Refers to "unobligated or discretionary time – the free time that remains after the demands of work, maintenance, and family and social obligations have been met" (Wankel & Sefton, 1992, pg. 155).

Mastery:

Refers to "the extent to which one regards one's life-chances as being under one's own control in contrast to being fatalistically ruled" (Pearlin & Schooler, 1978, pg. 5).

Physical Activity:

Refers to "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen, Powell, & Christenson, 1985, pg. 126).

Recall Decay:

Refers to "a decline in the ability to recall an event as the event recedes in time" (R. A. Johnson, Gerstein, & Rasinski, 1998, pg.356).

Self-Efficacy:

Refers to "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, pg. 3).

Teachable Moment:

Refers to "naturally occurring life transitions or health events thought to motivate individuals to spontaneously adopt risk-reducing health behaviours" (McBride, Emmons, & Lipkus, 2003, pg. 156).

Chapter 1
Introduction

1.1 Theme:

A health behaviour refers to "actions in which individuals engage that influence health. The impact can be negative, as with tobacco and other drug use and risky sexual behaviours, or positive, as with physical activity, fruit and vegetable consumption, and the wearing of helmets or seatbelts" (J. J. Prochaska, Spring, et al., 2008, pg. 183). Since approximately 60 to 64% of chronic disease deaths are attributed to an inability of individuals to participate in multiple healthy behaviours (Knoops, et al., 2004) positive behavioural changes could have a significant impact on the overall health of the general population (Haveman-Nies, et al., 2002; Knoops, et al., 2004; Meng, Maskarinec, Lee, & Kolonel, 1999) and a substantial impact on productivity, worker's compensation, and health care expenditures (Edington, 2001; Schuit, et al., 2002). Health care costs associated with physical inactivity is estimated at over $2 billion (Katzmarzyk, Gledhill, & Shephard, 2000), whereas costs attributable to smoking and alcohol consumption could reach $17 billion and $14.6 billion, respectively (Rehm, et al., 2007). As these health care expenditures continue to escalate, the primary prevention of unhealthy behaviours is imperative. Approximately 50 to 80% of individuals within the general population participate in multiple unhealthy behaviours (Berrigan, Dodd, Troiano, Krebs-Smith, & Barbash, 2003; Coups, Gaba, & Orleans, 2004; Fine, Philogene, Gramling, Coups, & Sinha, 2004) with physical inactivity, smoking, and excessive alcohol consumption being among the most prevalent (Coups, et al., 2004; Fine, et al., 2004; Klein-Geltink, Choi, & Fry, 2006). This co-occurrence of multiple unhealthy lifestyle behaviours provides justification for the development of effective and cost-efficient multiple behavioural change interventions (Bock, Marcus, Rossi, & Redding, 1998; Campbell, et al., 2000).

As the majority of behavioural studies have typically examined single behavioural change, the need for research strategies that focus on as well as implement multiple health behaviour change has arrived (Aarnio, Winter, Kujala, & Kaprio, 2002; Costakis, Dunnagan, & Haynes, 1999; Coups, et al., 2004; Nigg & Long, 2012; S. Solomon & Kington, 2002). Multiple health behaviour research attempts to identify, target, and

change as many health behaviours as possible in order to have the most significant impact on the health and well-being of the general population (J. J. Prochaska, Spring, et al., 2008). Although difficult to implement, health professionals have acknowledged that the benefits associated with multiple health behaviour change outweigh the current challenges (J. J. Prochaska, Nigg, Spring, Velicer, & Prochaska, 2010). Such advantages include a substantially greater impact on the occurrence and severity of morbidity and mortality (Nigg, et al., 2002; J. J. Prochaska, et al., 2010), the ability to evaluate the interrelationship between health behaviours (Nigg, et al., 1999; Tucker & Reicks, 2002), and the unique opportunity for the development of a choice-based approach in changing health behaviours (de Vries, Kremers, Smeets, & Reubsaet, 2008), while conserving time and resources and potentially minimizing health care expenditures (J. J. Prochaska, et al., 2010; Pronk, Peek, & Goldstein, 2004). Furthermore, health professionals regard multiple health behaviour interventions as being more relevant to real-world circumstances (J. J. Prochaska, et al., 2010). For these reasons, the development of effective interventions which stimulate the adoption and maintenance of multiple healthy behavioural lifestyles has become the primary focus of public health interventions (Haveman-Nies, et al., 2002).

Although multiple health behaviour research may represent a promising avenue in the prevention of chronic diseases (L. Gordon, Graves, Hawkes, & Eakin, 2007), several unanswered questions remain and need to be addressed by future research. As unhealthy behaviours demonstrate a tendency to cluster (Poortinga, 2007b; Raitakari, et al., 1995; Schuit, et al., 2002), evaluating co-variation of health behaviours could assist in the development of effective and cost-efficient public health interventions as programs could focus their time and resources on changing one or two health behaviours as opposed to improving three or four behaviours (Nigg, et al., 2002; J. O. Prochaska, 2008; Tucker & Reicks, 2002). Co-variation refers to "taking effective action on one behaviour increases the odds of taking effective action on a second behaviour" (J. O. Prochaska, 2008, pg. 282). While the interrelationship of health behaviours has been examined for several decades, by the turn of the century, little was known pertaining to the co-variation of health behaviours (Ory, Jordan, & Bazzarre, 2002). However, in recent years, the necessity for more effective public health strategies has led to a greater interest in

multiple behavioural research. In an attempt to examine the current literature pertaining to the co-variation of multiple health behaviours, subsequent sections of Chapter 2 outline and discuss the findings of a systematic review. Furthermore, while literature has been able to identify cognitive mechanisms that influence single behavioural change (Bock, et al., 1998; DiClemente, Prochaska, & Gibertini, 1985; Love, Davoli, & Thurman, 1996; O'Hea, et al., 2004), the role that cognitive mechanisms may have on multiple behavioural change is limited and requires further evaluation (Bock, et al., 1998; Nigg, et al., 2002).

While interventions typically serve as a focal point for the majority of multiple behavioural change research, observational studies could provide valuable insight into the interrelationship of multiple health behaviour change within natural environments. However, previous observational literature has incorporated several methodological limitations that may have compromised the findings of these studies. Such limitations have included cross-sectional study designs, small and unrepresentative samples of the general population, the use of dichotomous or categorical outcome variables, as well as the inability to assess cognitive mechanisms which may promote the adoption and maintenance of multiple health behaviours. Thus, the current study will attempt to address the aforementioned concerns of previous literature by using a large, nationally representative database to assess the longitudinal trajectories of multiple behavioural changes and potential cognitive mechanisms over several time intervals.

1.2 Objectives:

1) The primary objective is to evaluate co-variation among health behaviours; specifically alcohol consumption, physical activity, and smoking across multiple time intervals in a nationally representative sample.
2) The secondary objective is to examine whether mastery acts as a mediating cognitive mechanism that facilitates changes between multiple health behaviours.

1.3 Culmination of Work:

I initially acquired an interest in the multiple behavioural change discipline when examining the potential role that physical activity may play as a tobacco harm reduction

strategy. This literature review discussed how physical activity successfully fulfilled several of the criteria that characterize tobacco harm reduction strategies (W. deRuiter & Faulkner, 2006). Consequently, it was hypothesized that physical activity could reduce tobacco use and possibly assist individuals in achieving cessation (W. deRuiter & Faulkner, 2006). To investigate this theory, a cross-sectional study was undertaken in which physically active smokers were compared to their inactive counterparts within a nationally representative sample of Canadians (W. K. deRuiter, Faulkner, Cairney, & Veldhuizen, 2008). It appeared that physically active smokers represented a unique group of the smoking population as such individuals consumed fewer cigarettes per day and reported a greater likelihood of attempting cessation (W. K. deRuiter, et al., 2008). Although this empirical study provided evidence of an interrelationship between physical activity and smoking, the findings were cross-sectional and offered only a snapshot of the relationship between these two behaviours. Utilizing a longitudinal study design would be a more suitable method for evaluating multiple behavioural trajectories and thus seemed to be the next logical step in advancing my PhD studies. Therefore, this dissertation not only addresses the limitations that have been reported within previous empirical research, but it also represents a culmination of the work that I have accomplished during my PhD candidacy within the Department of Exercise Sciences at the University of Toronto.

Chapter 2
Literature Review

2.1 Importance of Multiple Health Behaviour Research:

To a considerable extent, health is a product of lifestyle behaviours. Generally, individuals who practice a greater number of healthy behaviours can expect a reduction in premature morbidity and mortality, a higher active life expectancy as well as an enhancement in quality of life (Ferrucci, et al., 1999; Knoops, et al., 2004). Unlike gender, aging, or genetics, lifestyle behaviours including excessive alcohol consumption, physical inactivity, smoking, and unhealthy dietary intake are modifiable. The adoption and maintenance of healthy behaviours could have a substantial effect on prolonging the onset of chronic diseases (L. Gordon, et al., 2007). Thus even the slightest improvements within these health behaviours could be substantially beneficial and significantly reduce the odds of developing chronic and/or debilitating diseases (Atkins & Clancy, 2004; Kvaavik, Batty, Ursin, Huxley, & Gale, 2010). Although these modifiable health behaviours continue to be the primary focus of public health programs (Haveman-Nies, et al., 2002), the majority of research has chosen to concentrate on single behavioural change as opposed to the modification of multiple health behaviours (Berg, et al., 2012; Costakis, et al., 1999; Coups, et al., 2004; Nigg, et al., 2002; Nigg & Long, 2012; Strecher, Wang, Derry, Wildenhaus, & Johnson, 2002). Contrary to single behavioural changes, modifying multiple behaviours requires the development of strategies and programs which promote the adoption and maintenance of two or more health behaviours either simultaneously or sequentially among high-risk individuals as well as the general population (J. J. Prochaska, Spring, et al., 2008).

As the presence of multiple risk factors accumulate, a synergistic effect among health behaviours is often observed resulting in an increase in susceptibility to mortality among men and women (Meng, Maskarinec, Lee, & Kolonel, 1999). This increased risk of mortality that is associated with the presence of multiple unhealthy behaviours is equivalent to the accumulation of 12 additional years to an individual's current age (Kvaavik, et al., 2010). Public health programs could be more cost-efficient as well as effective in reducing morbidity and mortality if they focus on changing multiple

behaviours as opposed to a single health behaviour (Chang, Hahn, Teutsch, & Hutwagner, 2001; Clark, Nigg, Greene, Riebe, & Saunders, 2002; Meng, et al., 1999; J. J. Prochaska & Prochaska, 2011). After all, if changing a single health behaviour can substantially reduce the risk of mortality among individuals, then modifying multiple health behaviours could have a substantially greater impact on the occurrence and severity of morbidity and mortality (Chang, et al., 2001; Haveman-Nies, et al., 2002; Knoops, et al., 2004; Kvaavik, et al., 2010; Meng, et al., 1999; Puska, et al., 1985).

The lack of an association between health behaviours would provide little justification for targeting multiple health behaviours. Consequently, health professionals would aim to change lifestyle behaviours independently which would require more resources to produce favourable results (M. F. Johnson, Nichols, Sallis, Calfas, & Hovell, 1998). However, since health behaviours often demonstrate co-occurrence, the identification of co-variation or gateway behaviours could have significant implications on the development of effective and cost-efficient health promotion programs (Emmons, Shadel, Linnan, Marcus, & Abrams, 1999; M. F. Johnson, et al., 1998; Nigg, et al., 1999; J. J. Prochaska & Prochaska, 2011; Tucker & Reicks, 2002). According to Nigg et al. (2002, pg. 676), a gateway behaviour refers to "a behaviour that, when intervened upon, has a positive influence on other behaviour changes". Gateway behaviours provide health professionals with an opportunity to allocate their time and resources towards one lifestyle behaviour which could potentially modify additional health behaviours while minimizing health care expenditures (Blakely, Dunnagan, Haynes, Moore, & Pelican, 2004; Nigg, et al., 1999; Pronk, Peek, et al., 2004). Thus, gateway behaviours could provide health professionals with an opportunity to indirectly facilitate the adoption and maintenance of additional health behaviours (Costakis, et al., 1999). Physical activity is one of the more commonly evaluated gateway behaviours. Evidence suggests that physical activity could act as a potential gateway behaviour for enhancing dietary intake (Blakely, et al., 2004; Reedy, Haines, & Campbell, 2005; Tucker & Reicks, 2002), reducing/quitting smoking (Costakis, et al., 1999; W. K. deRuiter, et al., 2008; Gauthier, Snelling, & King, 2012; T. K. King, Marcus, Pinto, Emmons, & Abrams, 1996), and moderating alcohol consumption (Rosal, Ockene, Hurley, & Reiff, 2000). Positive changes in smoking behaviour may also have the capacity to act as a potential gateway

behaviour for reducing alcohol consumption (Miller, Hedrick, & Taylor, 1983) and vice versa (Breslau, Peterson, Schultz, Andreski, & Chilcoat, 1996).

Since multiple behavioural change programs assist individuals in modifying several lifestyle risk factors, these interventions allow the unique opportunity for individuals to choose which behaviours to intervene upon as well as the chance to prioritize the sequence in which these healthy behaviours are adopted (de Vries, Kremers, et al., 2008). Abstinence from smoking and excessive alcohol consumption are challenging for the majority of individuals. As opposed to modifying a "challenging" behaviour at the onset of behavioural change, smokers or alcoholics may opt to concentrate on other lifestyle risk factors that they perceive as being easier to adopt and maintain (Garrett, et al., 2004). For example, high risk drinkers prefer to change smoking, physical activity levels or dietary habits before changing their alcohol consumption (Rosal, et al., 2000). Smokers also demonstrate similar behavioural choices as they report a greater motivation to change their physical activity and/or dietary habits compared to selecting smoking cessation as their highest priority (Campbell, et al., 2000). Focusing one's attention on attenuating other unhealthy behaviours before attempting smoking cessation could produce more success and greater benefits compared to efforts that attempt to initially change smoking habits (Sherwood, Hennrikus, Jeffery, Lando, & Murray, 2000). Health professionals who emphasize changing a single behaviour may fail to recognize an individual's motivational readiness to adopt different behaviours; focusing on smoking would miss the fact that smokers are also ready to change diet and/or physical activity (Campbell, et al., 2000). Asking an individual what he/she is interested in changing (choice-based system) is an effective method in identifying and prioritizing health behaviours as it may provide the individual with a sense of motivation, empowerment and self-efficacy to become more successful in adopting and maintaining additional and more challenging behaviours (Ampt, et al., 2009; Berg, et al., 2012; Campbell, et al., 2000; Strecher, et al., 2002). Thus, changing a benign behaviour could act as a potential gateway behaviour for changing more difficult behaviours (Berg, et al., 2012; Rosal, et al., 2000; Strecher, et al., 2002). However, this harm reduction approach may lead to the emergence of a possible drawback as individuals who possess a high motivation to change a relatively benign behaviour may experience benefits of lesser magnitude

compared to individuals who decide to change a more critical or life-threatening behaviour (Campbell, et al., 2000). Hence, a choice-based system may provide individuals with the preference of either achieving greater health benefits or enhancing their confidence in adopting further healthy behaviours (Kukafka, Khan, Kaufman, & Mark, 2009). One example of a choice-based approach, safer smoking tips, has been described by Cunningham et al. (2006, 2007). Smokers who were provided knowledge of safer smoking guidelines prior to discussing perceived choices believed that public health organizations provided greater options for their smoking behaviour (Cunningham, Selby, & Faulkner, 2007). Furthermore, information on safer smoking guidelines did not appear to undermine behavioural changes as individuals demonstrated a reduction in tobacco use (Cunningham, Faulkner, Selby, & Cordingley, 2006).

As multiple health behaviour change research assists individuals in identifying, targeting, and changing as many health behaviours as possible (J. J. Prochaska, Spring, et al., 2008), there is some concern that attempting to change health behaviours simultaneously may obstruct or overwhelm behavioural change (Berg, et al., 2012). To some extent, this concern is warranted. In a natural environment, pregnant women who used multiple substances were significantly less likely to quit consuming alcoholic and caffeinated beverages, but not cigarette smoking (Pirie, Lando, Curry, McBride, & Grothaus, 2000). However, in comparing the effectiveness of single and multiple health behavioural change interventions, Prochaska et al. (2006) concluded that after the adjustment of demographic as well as smoking characteristics, smoking abstinence rates were similar between both interventions. Although multiple health interventions appear to be as effective at promoting smoking cessation as interventions which attempt to modify a single behaviour, evidence to support the development of multiple behavioural change interventions was apparent as this type of intervention was able to facilitate favourable changes in additional behaviours (diet and/or sun exposure) (J. J. Prochaska, Velicer, Prochaska, Delucchi, & Hall, 2006).

Adopting and maintaining multiple health behaviours would not only be a daunting and challenging task for an individual (Berg, et al., 2012; Nigg & Long, 2012; Strecher, et al., 2002), but may require the integration of health care organizations as well as the service of multiple health professionals with various expertise (J. J. Prochaska, et al., 2010).

However, behavioural change professionals agree that the benefits of multiple behaviour change interventions often outweigh the associated challenges (J. J. Prochaska, et al., 2010). The North Karelia Project, Project PREVENT, and Mediterranean Lifestyle Project are examples of interventions that have been successful in changing multiple health behaviours (Emmons, McBride, Puleo, Pollak, Clipp, et al., 2005; Puska, et al., 1985; Toobert, et al., 2007; Toobert, Strycker, Glasgow, Barrera Jr, & Angell, 2005).

2.2 Prevalence of Multiple Health Behaviours/Risk Factors:

While the benefits of participating in healthy lifestyles are widely known, the majority of the general population continues to demonstrate an inability to adhere to such recommendations (Berrigan, et al., 2003; Coups, et al., 2004; Keller, Maddock, Hannover, Thyrian, & Basler, 2008). The most prevalent independent health risk factor within the United States appears to be physical inactivity as the majority of individuals, 58 to 69%, do not participate in regular levels of physical activity (Coups, et al., 2004; Fine, et al., 2004; Pronk, Anderson, et al., 2004). Following closely behind physical inactivity, overweight/obesity is an another risk factor that is prevalent among the majority of Americans (Coups, et al., 2004; Fine, et al., 2004; Pronk, Anderson, et al., 2004). This is not surprising considering the strong relationship between physical inactivity and being overweight/obesity (Fine, et al., 2004). For the purpose of this analysis, obesity was considered a risk factor rather than a behaviour as it is a product of physical inactivity and/or unhealthy dietary habits. Unhealthy dietary habits, a lack of fruit and vegetables and/or high dietary fat consumption, are also common among Americans as 35 to 66% of individuals possess low quality diets (Berrigan, et al., 2003; Pronk, Anderson, et al., 2004). Although they can be more harmful, these behaviours are less prevalent as 20 to 32% of individuals are smokers and 8 to 26% of the general population drink excessively (Berrigan, et al., 2003; Coups, et al., 2004; Fine, et al., 2004).

While research has attempted to identify the occurrence of multiple unhealthy behaviours, the prevalence of unhealthy behavioural combinations can vary substantially between populations as well as the types of risk factors evaluated. Literature reports only a small proportion, 3 to 15%, of the general population possess no unhealthy behaviours

(Berrigan, et al., 2003; Coups, et al., 2004; de Vries, Kremers, et al., 2008; Fine, et al., 2004; Pronk, Anderson, et al., 2004; Schuit, et al., 2002). Unfortunately, engaging in multiple unhealthy behaviours is exceptionally prevalent among the United States general population as 50 to 80% of individuals exhibit several lifestyle risk factors including physical inactivity, being overweight, unhealthy dietary intake, smoking, and/or excessive alcohol consumption (Berrigan, et al., 2003; Coups, et al., 2004; Fine, et al., 2004). Berrigan et al. (2003) reported that over 40% of the United States population partakes in either smoking or excessive alcohol consumption as well as one or more other risk factors pertaining to dietary intake and/or physical inactivity. The most prevalent pairwise combination of unhealthy behaviours among the general population appears to be physical inactivity and being overweight/obese (26.4%) (Fine, et al., 2004). Physical inactivity, being overweight/obese, and smoking is the most common combination of three risk factors (5.5%) (Fine, et al., 2004).

Canadians appear to state more conservative estimates as 15 to 21% report possessing no unhealthy behaviours, while 39 to 58% of individuals possess multiple risk factors (Klein-Geltink, et al., 2006; Makrides, Sawatzky, Petrie, & Veinot, 2010). Similar to the prevalence rates within the United States, physical inactivity is the most prevalent risk factor (53.5%) among Canadians, followed by overweight/obesity (44.8%), smoking (21.5%), and excessive alcohol consumption (6.0%) (Klein-Geltink, et al., 2006). However, according to Makrides et al. (2010), the most prevalent risk factors among Canadians were being overweight (70%), a physically inactive lifestyle (49%), and smoking (20%). The most common pairwise combination of risk factors among Canadians is physical inactivity and being overweight/obese (19.0%), while physical inactivity, being overweight/obesity, and smoking is the most prevalent combination of three unhealthy behaviours (Klein-Geltink, et al., 2006).

Even though Canada and the United States demonstrate similar risk factor trends, the observed variations in prevalence rates could be attributed to the utilization of different criteria employed to define each unhealthy behaviour. Unlike their United States counterparts (Berrigan, et al., 2003; Coups, et al., 2004; Fine, et al., 2004), Klein-Geltink et al. (2006) did not consider the occurrence of binge drinking when defining their criteria for excessive alcohol consumption. Furthermore, Klein-Geltink et al. (2006) also

categorized occasional smokers as non-smokers and used a conservative criteria, <1.5 kilocalories/kilograms/day (kcal/kg/day), in classifying individuals as being physically inactive. Regardless of which criteria are employed to define unhealthy behaviours, it is apparent that a substantial proportion of the general population need to adopt healthier lifestyles.

2.3 Clustering of Health Behaviours:

The occurrence of multiple unhealthy behaviours is not random as specific lifestyle behaviours have shown a tendency to cluster among one another (Driskell, Dyment, Mauriello, Castle, & Sherman, 2008; Poortinga, 2007b; Schuit, et al., 2002). Clustering is a concept that refers to a grouping of two or more health behaviours that is "more prevalent than can be expected on the basis of the prevalence of separate risk factors" (Schuit, et al., 2002, pg. 219). In regards to the clustering of pairwise combinations of health behaviours, smoking and excessive alcohol consumption demonstrated the strongest association of clustering as smokers reported a 2.4 times increase in the odds of excessive alcohol consumption compared to non-smokers (Schuit, et al., 2002). Others have also reported a strong association between both smoking and excessive consumption of alcohol (Chou, 2008; Poortinga, 2007b) suggesting that the strongest clustering occurs between the most difficult behaviours to change. As outlined in Table 1, several other clusters of modifiable lifestyle risk factors have been identified in young/middle aged adult populations including excessive alcohol consumption and unhealthy dietary intake, smoking and deficient dietary habits, and unhealthy dietary habits and physical inactivity (Poortinga, 2007b; Schuit, et al., 2002). Contrasting results have been observed for other combinations of health behaviours such as smoking and physical inactivity. Some have demonstrated significant pairwise clustering between smoking and physical inactivity (Schuit, et al., 2002), whereas others have observed significant inverse clustering between these two behaviours (Poortinga, 2007b). As a greater understanding of behavioural clustering is acquired, public health professionals will be able to use this knowledge to design and implement effective preventive health promotion programs (Schuit, et al., 2002).

Table 1: Pairwise Clustering of Health Behaviours

	Schuit et al. (2002)	Poortinga et al. (2007)		Chou et al. (2008)	
	Men and Women	Men	Women	Men	Women
Smoking & Excessive Drinking	2.38‡	1.90***	2.88***	1.25***	10.04***
Smoking & Physical Inactivity	1.39‡	0.85**	0.81**	0.22***	0.77***
Smoking & Unhealthy Diet	1.65‡	2.31***	2.75***	0.35***	0.53
Physical Inactivity & Unhealthy Diet	1.57‡	1.19**	1.46***	0.03***	0.12***
Physical Inactivity & Excessive Drinking	1.04	0.77***	0.84*	0.42	0.66
Unhealthy Diet & Excessive Drinking	1.51‡	1.48***	1.63***	0.53	0.27

‡ Prevalence odds ratio was significant, but the level of significance is not known.
* Prevalence odds ratio was significant at $p \leq 0.05$; ** Significant at $p \leq 0.01$; ***Significant at $p \leq 0.001$.

2.4 Behavioural Changes Over Time:

Due to the strong association between health behaviours and various health indicators, health care professionals and policy makers have begun to recognize the importance that behavioural change may have on population health (Orleans, Gruman, Ulmer, Emont, & Hollendonner, 1999). Smoking and alcohol consumption are perceived as being more difficult to change. Consequently these behaviours demonstrate relatively high to moderate stability as they require continuous self-restraint and abstinence compared to other health enhancing behaviours such as physical activity or dietary intake which exhibit greater levels of instability (Boniface, Cottee, Neal, & Skinner, 2001; de Vries, van 't Riet, et al., 2008; Mulder, Ranchor, Sanderman, Bouma, & van den Heuvel, 1998; Paavola, Vartiainen, & Haukkala, 2004; Prattala, Karisto, & Berg, 1994).

In the past, empirical research has demonstrated substantial behavioural changes, either positive or negative, in physical activity (Audrain-McGovern, Rodriguez, & Moss, 2003; Jacobs, et al., 1991; I. M. Lee, Paffenbarger, & Hsieh, 1992; Terry-McElrath & O'Malley, 2011), tobacco use (P. I. Frank, Morris, Frank, Hazell, & Hirsch, 2004; Li, et al., 2009; Terry-McElrath & O'Malley, 2011), and alcohol consumption (Costanzo, et al., 2007; Li, et al., 2009; Terry-McElrath & O'Malley, 2011; Vlasoff, et al., 2008). However, in regards to multiple behavioural changes, research is limited. One study of particular

interest was conducted over a 4 year period by Mulder et al. (1998). It was observed that only a small proportion of men, 10%, were able to change multiple health behaviours (Mulder, et al., 1998). Of these men who reported multiple behavioural changes, 40% had adopted two or more healthy behaviours, 40% made one healthy as well as one unhealthy behavioural change, and the remaining 20% had taken up two or more unhealthy risk factors (Mulder, et al., 1998). In most cases, the adoption of multiple health behaviours was associated with at least one healthy behavioural change. However, in nearly half of these individuals, any benefits obtained through a positive behavioural change could be potentially offset by a negative behavioural change. It is not uncommon for a positive behavioural change to subsequently result in the adoption of a negative behaviour. Smoking cessation is often accompanied with weight gain (Chinn, et al., 2005), while improvements in physical activity levels are associated with an increase in dietary fat consumption (Dutton, Napolitano, Whiteley, & Marcus, 2008). These findings reveal that, without the assistance of an intervention, only a small proportion of individuals are able or willing to change multiple behaviours. While interventions have reported greater success in adopting multiple health behaviours (Emmons, McBride, Puleo, Pollak, Clipp, et al., 2005; Vandelanotte, Reeves, Brug, & De Bourdeaudhuij, 2008), the results of observational studies should not be overlooked as they may be more applicable to real-world circumstances.

2.5 Correlates of Health Behaviours:

Understanding the correlates of unhealthy behaviours can assist public health professionals in identifying high risk groups of individuals who are more likely to possess multiple unhealthy lifestyles (Berrigan, et al., 2003; Poortinga, 2007b; Schuit, et al., 2002). Once identified, such individuals could be targeted by public health programs. Individuals who are male, young or middle aged, divorced, separated, or widowed, with lower levels of education, and lower incomes demonstrate a tendency to possess multiple unhealthy behaviours (Berrigan, et al., 2003; Fine, et al., 2004; Laaksonen, Prattala, & Lahelma, 2003; Li, et al., 2009; Prattala, et al., 1994; Rosal, et al., 2001). This suggests that disadvantaged individuals may benefit most from adopting and maintaining healthy behaviours. Of these demographic characteristics, age and education appear to be less

important in regards to behavioural change as these qualities have demonstrated a marginal effect on the stability of health behaviours over a 4 year period (Mulder, et al., 1998). Consequently, Mulder et al. (1998) suggested that additional characteristics may have a more significant influence on behavioural change. Findings presented by Boniface et al. (2001) demonstrated that the adoption or maintenance of healthy behaviours was associated with full-time employment, higher education as well as higher social class. Disadvantaged individuals may need to be targeted by health professionals as they appear to experience difficulty in achieving healthy behavioural changes.

Although the identification of demographic characteristics is essential in improving public health, these characteristics are typically unchangeable. Understanding the cognitive mechanisms which assist individuals in adopting and maintaining multiple behavioural change is necessary (J. J. Prochaska & Sallis, 2004) as they are often modifiable (Pederson, Koval, McGrady, & Tyas, 1998) and essential mechanisms in the behavioural change process (DiClemente, et al., 1985; Love, et al., 1996). One such cognitive mechanism is mastery. As a cognitive mechanism, mastery has gained considerable attention. Similar to self-efficacy, mastery is a concept that is related to personal control (Pearlin & Schooler, 1978). Mastery refers to "the extent to which one regards one's life-chances as being under one's own control in contrast to being fatalistically ruled" (Pearlin & Schooler, 1978, pg. 5). Mastery levels, which are often a result of one's previous successes and failures, can dictate the number and type of potentially stressful events an individual can manage, the magnitude of effort exerted by the individual to resolve such stressful events, and the amount of resiliency that is demonstrated during difficult situations (Turner & Roszell, 1994). During one's lifetime, the trajectory of perceived control resembles an inverted "U" as adolescence and early adulthood represent a period in which individuals experience an increase in perceived control (Mirowsky & Ross, 2007). As middle age is reached, one's perception of control begins to steadily decline (Mirowsky, 1995; Mirowsky & Ross, 2007) with elderly individuals reporting the lowest levels control (Mirowsky, 1995).

In previous literature, mastery has demonstrated a significant association with smoking status and smoking relapse as it appears to play a role in reducing the urge to smoke (O'Connell, Gerkovich, & Cook, 1995; Pederson, et al., 1998). Mastery has also

exhibited a similar association with alcohol dependence suggesting that alcoholics believe that their drinking habits are under their control (Prescott, Neale, Corey, & Kendler, 1997). These findings suggest that mastery is associated with smoking and alcohol consumption and thus could be an essential mechanism in behavioural change. However, other studies have shown conflicting results and have been unable to establish an association between mastery and smoking as well as alcohol consumption (Allison, Adlaf, Ialomiteanu, & Rehm, 1999; Sneed, Morisky, Rotheram-Borus, Ebin, & Malotte, 2001). These contrasting findings could possibly be explained by differences in study design, study sample, and variations in the measurement of mastery. A cross-sectional study design has been a popular choice among many researchers (Allison, et al., 1999; Pederson, et al., 1998; Prescott, et al., 1997), followed by a retrospective (O'Connell, et al., 1995) or longitudinal design (Sneed, et al., 2001). The recruitment of a small sample (n = 57) (O'Connell, et al., 1995), and various study samples, adolescents (Pederson, et al., 1998; Sneed, et al., 2001), young adults (Allison, et al., 1999; Prescott, et al., 1997), and middle aged adults (O'Connell, et al., 1995), could also be responsible for any discrepancies in the findings. Finally, various measures of mastery were employed between studies. This could be the most likely explanation as to why the findings of these studies are conflicting. A global mastery scale developed by Pearlin and Schooler (1978) was utilized by Sneed et al. (2001), Allison et al. (1999), and Pederson et al. (1998). Prescott et al. (1997) employed the Powerlessness Scale (Maddi, Kobasa, & Hoover, 1979), whereas Apter's Reversal Theory (Apter, 1989) was employed by O'Connell et al. (1995). The use of various mastery scales may have produced inconsistent findings and thus making it difficult to compare results.

The effect of mastery on behavioural changes extends beyond smoking and alcohol consumption as it appears to be essential in the participation of physical activity. Although active exercisers and non-exercisers reported similar levels of mastery during an exercise intervention, higher levels of mastery were observed among exercisers during the follow-up period (Sorensen, 1997). These findings suggest that improvements in mastery are related to recent participation of a behaviour (Sorensen, 1997). Others have confirmed such findings (Sorensen, Anderssen, Hjerman, Holme, & Ursin, 1997). Furthermore, a reciprocal association was also observed as mastery was a significant

predictor of exercise compliance (Sorensen, et al., 1997). Unlike the aforementioned interventions, in an observational study, Cairney et al. (2005) reported a positive relationship between mastery and leisure-time physical activity among a sample of elderly Canadians. Although this relationship had reached statistical significance, the strength of the correlation (r) was weak (r = 0.16) (Cairney, Faught, Hay, Wade, & Corna, 2005). Prior to the research conducted by Cairney et al. (2005), Allison et al. (1999) had examined the effects of mastery as well as other social determinants on health behaviours among young adults. Allison et al. (1999) found no association between mastery and physical inactivity. Allison et al. (1999) suggested that these non-significant associations could be the result of using determinants that were not behaviour specific, but rather global determinants (e.g., overall mastery). Dergenace et al. (2005) also did not observe a significant association between mastery and physical activity in a sample of elderly Mexican Americans and European Americans. When employing cross-sectional study designs, previous studies were either unable to observe whether a sense of mastery was associated with physical activity (Allison, et al., 1999; Dergance, Mouton, Lichtenstein, & Hazuda, 2005) or identified a weak relationship between mastery and physical activity (Cairney, et al., 2005). Perhaps longitudinal studies would be more appropriate for assessing whether mastery is associated with changes in health behaviours (Cairney, Faulkner, Veldhuizen, & Wade, 2009). However, it is also conceivable that interventions are necessary before an association between mastery and physical activity can be observed.

Although mastery could be associated with the presence of specific health behaviours, the association between mastery and behavioural change has had little examination. Furthermore, to my knowledge, the potential mediating effects of mastery on changes in multiple behaviours is also non-existent and thus deserves further evaluation. If mastery is found to be associated with multiple behavioural change, then strategies for increasing mastery would become an integral component of behavioural change interventions (Pederson, et al., 1998).

2.6 Theory Based Multiple Behavioural Change Research:

Although it is unlikely that a single theory can fully explain the process of change for every health behaviour encountered, it is expected that one theory could be more appropriate in describing this process than others (Langlois & Hallam, 2010). Due to its comprehensive approach, previous empirical research has typically utilized the Trans-Theoretical Model to assess multiple behavioural change (Herrick, Stone, & Mettler, 1997). This model has been used to describe how individuals change detrimental lifestyle behaviours by adopting and maintaining healthy behaviours (Rosen, 2000). Briefly, individuals must progress through a series of stages which represent their motivational readiness for behavioural change. Upon completing each of the five stages of change, individuals will have successfully adopted and maintained a healthy behaviour (DiClemente, et al., 1985; Doherty, Steptoe, Rink, Kendrick, & Hilton, 1998). The five stages of change include the precontemplation, contemplation, preparation, action, and maintenance stages. The first three stages of change represent periods of time in which individuals intend to change their behaviour. Individuals who do not intend to change a particular behaviour within the next 6 months are in the precontemplation stage. In the contemplation stage, individuals plan to change their behaviour within the next 6 months. The preparation stage represents a period in which the individual contemplates changing their behaviour within the next 30 days. In the action stage, the individual has taken action and adopted the new health behaviour for less than 6 months, whereas individuals participating in the new behaviour for a minimum of 6 months are classified as being in the maintenance stage (J. O. Prochaska, et al., 1994). The Trans-Theoretical Model also includes three additional components; processes of change, decisional balance, and self-efficacy. The processes of change describe activities individuals may use to progress through the stages of change (J. O. Prochaska, et al., 1994). Decisional balance involves the individual's perception of the benefits as well as barriers of undertaking a behavioural change (J. O. Prochaska, et al., 1994). Individuals perceive higher barriers and fewer benefits during the earlier stages of behavioural change, whereas perceived benefits tend to outweigh the barriers in the later stages of change (J. O. Prochaska, et al., 1994). The crossover point in which the perceived benefits outweigh the perceived barriers appears to occur before individuals begin to participate in the health behaviour, usually between

the contemplation and action stages (J. O. Prochaska, et al., 1994). Self-efficacy refers to "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, pg. 3). Self-efficacy is not only essential in the initiation of behaviour change, but the maintenance of such a change as well (DiClemente, et al., 1985; Love, et al., 1996; Meland, Maeland, & Laerum, 1999; Tucker & Reicks, 2002). The Trans-Theoretical Model encourages interventions to be stage-specific in the messages and resources they utilize in assisting individuals to adopt and maintain healthy behaviours (Feinstein & Feinstein, 2001).

Although the Trans-Theoretical Model is commonly employed for evaluating health behaviour change (Weinstein, Rothman, & Sutton, 1998), it is not without its limitations. Classification of the stages of change can often be difficult and relies on an accurate self-reported description of an individual's motivational readiness to change a particular health behaviour (Weinstein, et al., 1998). Furthermore, progression through the stages of change is not necessarily associated with significant improvements in a health behaviour (Callaghan, Taykor, & Cunningham, 2007). Finally, it is important to remember that behaviour change is challenging and although an individual could be motivated and have good intentions to change a particular health behaviour, it is possible that their intentions may not correspond to the adoption of a favourable behaviour (Callaghan, et al., 2007).

The Theory of Planned Behaviour, an extension of the Theory of Reasoned Action, is useful when an individual perceives little to no control over factors, events, information, skills, or opportunities (Ajzen, 1985, 1991). According to the Theory of Planned Behaviour, an individual's intentions are a primary determinant as to whether or not they engage in a particular behaviour (Ajzen, 1991). Intentions are "indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour" (Ajzen, 1991, pg. 181). Similar to the Theory of Reasoned Action, intentions are influenced by their attitudes and subjective norms; an individual's evaluation of participating in a behaviour and their perception of the social pressure they may experience from significant others for performing a behaviour, respectively (Ajzen, 1985, 1991). Building on the Theory of Reasoned Action, the Theory of Planned Behaviour incorporates perceived behavioural control which can influence the

performance of a behaviour either directly or indirectly through intentions (Ajzen, 1991). Perceived behavioural control refers to an individual's perception of the degree of difficulty in performing a behaviour (Ajzen, 1991). When individuals perceive complete control over opportunities, factors, and resources as well as fewer challenges with performing a behaviour, the Theory of Planned Behaviour acts similar to the Theory of Reasoned Action (Ajzen, 1985, 1991). More positive attitudes and subjective norms as well as greater perceived behavioural control often lead to stronger intentions which result in a greater likelihood of performing a chosen behaviour (Ajzen, 1991). As with other theories, the Theory of Planned Behaviour has a number of limitations; intentions may change over time or new information may become available that interrupts an individual's intentions (Ajzen, 1985). Evidence of previous empirical studies have demonstrated that intentions and perceived behavioural control are related to soft drink consumption and television viewing (de Bruijn & van den Putte, 2009). Others have shown that positive attitudes, subjective norms, and perceptions of behavioural control are associated with stronger intentions to engage in physical activity and a healthy diet (Andrykowski, Beacham, Schmidt, & Harper, 2006). To some extent, the Theory of Planned Behaviour may provide essential information to guide the secondary objective of this study; whether mastery acts as a mediating mechanism that facilitates co-variation. If perceived control, as measured by mastery, mediates the co-variation of health behaviours, the Theory of Planned Behaviour may provide insight into how mastery assists and interacts with additional mechanisms in accomplishing multiple behavioural changes.

2.7 Systematic Review:

To this point, the current literature review has focused upon the importance of multiple health behaviour change research, the prevalence and clustering of multiple health behaviours, the occurrence of behavioural change over time, as well as correlates of health behaviours. This literature has shown that multiple health behaviour change can significantly reduce the occurrence of mortality, may assist in the identification of potential gateway behaviours, and allow individuals an opportunity to select which behaviours they are interested in changing. In addition, health professionals should focus

their attention and resources on changing physical inactivity, smoking, and excessive alcohol consumption as these unhealthy lifestyle behaviours are among the most prevalent within the general population. Furthermore, although multiple behavioural change is achieved by only a small proportion of individuals, the majority of such individuals are able to attain at least one positive behavioural change.

Overall, multiple health behaviour change may represent the future of chronic disease prevention (L. Gordon, et al., 2007), however there are several questions pertaining to this field of research that need to be answered. As previously mentioned, health professionals are aware of the "why" and "what" of multiple health behaviour change, however a primary concern regarding this discipline of research is the interrelationship between health behaviours and how changes in one behaviour may influence subsequent behavioural changes (Bock, et al., 1998; Clark, et al., 2005; Costakis, et al., 1999; Nigg, et al., 2002; Unger, 1996). The purpose of this systematic review was to examine the current scientific evidence of multiple health behaviour change with the specific focus of examining co-variation; whether changes in one health behaviour are significantly associated with changes in additional health behaviours. It's expected that this systematic review will not only provide valuable insight in the understanding of co-variation, but identify limitations that have been encountered by previous empirical research. The resolution of these limitations will thereby contribute to the uniqueness and novelty of this dissertation.

In an effort to address the purpose of this systematic review, relevant medical subject headings (MESH) and non-MESH terms were entered into Pubmed and Ovid medline databases. These terms included motor activity, physical fitness, leisure activities, sports, exercise, exercise therapy, physical exertion, physical activity, alcohol, alcoholism, alcohol drinking, alcoholics, alcoholic intoxication, smoking, smoking cessation, tobacco, tobacco use cessation, tobacco use disorder, cigarette, health behavior, attitude to health, risk factors, health promotion, multiple health behavior, multiple health behavior change, multiple risk factor, multiple lifestyle behavior, and gateway behavior. These terms were used independently and in BOOLEAN combination. Furthermore, the database search was complemented by a manual review of reference lists from the retrieved database articles. In an attempt to provide greater focus to each literature search, human and

English limits were utilized. This systematic review also employed a publication date range of thirty years; 1982 to July 2012. This range was chosen due to the fact that multiple health behaviour change is a relatively new discipline of research and the most influential studies would be encompassed within this thirty year period. Excluded from this review were studies that had analysed data that was collected, either at baseline and/or follow-up, from an experimental or quasi-experimental study. The justification for excluding these studies was twofold. First, experimental and quasi-experimental study designs involve the exposure or deprivation of some condition to a specific group(s) and, in the case of experimental designs, may include the process of randomly assigning study participants to various treatment and/or control groups. As this dissertation intends to employ observational data to evaluate co-variation between health behaviours, comparing the findings of experimental/quasi-experimental studies with those of observational studies could be challenging as well as inappropriate. Second, the recruitment of individuals with no intention of adopting a healthy behaviour has been a challenge for previous interventions (Emmons, Marcus, Linnan, Rossi, & Abrams, 1994; Stotts, Schmitz, & Grabowski, 2003). Thus, the findings could be subjected to bias as only individuals who are interested in behavioural change represent the recruited sample. It is likely that population-based observational studies recruit individuals with no intention of attempting behavioural changes. Consequently, the findings of observational studies would be difficult to compare with those of experimental research.

2.7.1 Systematic Review of Cross-Sectional Studies:

Nine observational cross-sectional studies were retrieved. Table 2 summarizes the recruited sample, behavioural measurements, reported findings, and the study limitations for each of the nine observational cross-sectional studies. Each cross-sectional study was critiqued based on sufficient sample size, generalizability to the general population, the analysis of potential cognitive-behavioural mediating mechanisms, and whether health behaviours were adequately measured. This critique of cross-sectional studies is presented in Table 3.

In order to fulfill the appropriate sample size criterion, researchers could not acknowledge that sample size was a possible limitation for the findings that they

observed. Each of the nine cross-sectional studies identified through the systematic review had recruited an adequate sample size.

Only two of the nine cross-sectional studies had recruited a sample of individuals that were representative of the general population (De Leon, et al., 2007; Lippke, Nigg, & Maddock, 2012). However, in the case of Lippke et al. (2012), two of three studies had recruited a representative sample of the general population, while their third study had included a sample of people with diabetes. Others had enrolled specific subgroups of the general population including individuals with at least one chronic disease (Boudreaux, Francis, Carmack Taylor, Scarinci, & Brantley, 2003; Boyle, O'Connor, Pronk, & Tan, 1998; Finnegan & Suler, 1985), university students (Keller, et al., 2008), smokers (T. K. King, et al., 1996) and pregnant women (Pirie, et al., 2000).

As discussed in preceding as well as forthcoming sections, cognitive behavioural mechanisms including mastery, motivational readiness and self-efficacy can influence behavioural change. Thus, the effects of cognitive mediating mechanisms on the co-variation of multiple health behaviours should be examined (Muehrer, 2000; J. J. Prochaska & Prochaska, 2011). Not one of the cross-sectional studies evaluated in this systematic review had examined the potential mediating effects of cognitive mechanisms in the co-variation of health behaviours.

The evaluation of health behaviour variables was also assessed for each cross-sectional study. For the purposes of this systematic review, cross-sectional studies had met the criterion for adequate measurements of health behaviours if they had adopted one of two measures: 1) the utilization of continuous variables to assess each health behaviour or 2) the use of an established theory pertaining to health behaviour change. As discussed in more detail in subsequent sections, continuous variables are not restricted by specific criteria or cut-off points and thus could be more appropriate for examining behavioural change. The second component of this criterion relies on the use of an established health behaviour change theory that specifically evaluates how changes in one behaviour influences or produces changes in an additional behaviour. The Trans-Theoretical Model could be an example as it is a common and appropriate model to assess multiple behavioural change (Herrick, et al., 1997). Studies could establish evidence of co-variation between behaviours by examining the association between the stages of change

or self-efficacy levels. The majority of cross-sectional studies, six of nine, had fulfilled this criterion (Boudreaux, et al., 2003; Boyle, et al., 1998; Garrett, et al., 2004; Keller, et al., 2008; T. K. King, et al., 1996; Lippke, et al., 2012) by integrating the Trans-Theoretical Model. In addition to the Trans-Theoretical Model, Lippke et al. (2012) found evidence of a transfer effect in which the knowledge and confidence acquired in changing one behaviour was used to influence and assist in the adoption and maintenance of additional health behaviours. Not one of the nine cross-sectional studies had employed continuous behavioural variables. It is important that each of the retrieved articles for this systematic review fulfill the abovementioned guidelines. If these criteria were not satisfied, the internal and external validity could be susceptible to bias. Furthermore, non-compliance with such guidelines may direct future research and contribute to the knowledge pertaining to multiple behavioural change research.

Table 2: Cross-Sectional Multiple Health Behavioural Change Studies

Reference	Sample	Measurements	Results	Limitations
Boudreaux et al., 2003	- 270 ever smokers. - Low-income primary care patients. - Mean age of 47 years. - Majority of individuals were minorities (53%) and female (74%). - Married individuals represented 42% of the sample.	- Stages of change for exercise. - 5-item self-efficacy for exercise. - 16-item decisional balance for exercise. - Stages of change for smoking. - 20-item self-efficacy for smoking. - 18-item decisional balance measure for smoking.	- Stages of change for exercise was not related to the stages of change for smoking. - More positive views towards smoking was associated with more negative views of exercise and vice versa. - Self-efficacy between two behaviours was significantly associated.	- Variations in stages of change, decisional balance, and self-efficacy. - Sample consisted of low-income primary care patients of which 75% of participants had at least one chronic illness. Generalizability may be limited. - Potential mediating cognitive-behavioural mechanisms were not assessed.
Boyle et al., 1998	- 6,152 members of a Health Maintenance Organization (HMO). - Over 40 years old. - 51.8% were between 40 and 59 years of age. - Diagnosed with at least one chronic disease. - 73.0% were married. - Caucasians represented 94.8%. - 62.9% of individuals had acquired more than a high school education.	- Stages of change for physical activity and smoking.	- Low correlations (r) were observed between readiness to change smoking and readiness to change physical activity.	- Sample included an HMO population in a specific geographical area. - May not be generalizable as individuals with at least one chronic disease were oversampled. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 2: Cross-Sectional Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
de Leon et al., 2007	- Four samples were recruited. Two were recruited from the United States, while the remaining two samples came from Basque Country. Both locations were sampled in 1992 and once again 1996. - US samples were recruited through the National Household Survey on Drug Abuse, while the Spanish samples were obtained from the Basque Community Household Survey on General Health. - Sample sizes included 21,578 in 1992 and 13,731 in 1996 from the US, and 3,876 in 1992 and 2,786 in 1996 from Basque Country. - Participants were over 18 years of age.	- Ever smokers: smoked more than 100 days (US) or smoked more than 100 cigarettes (Basque Country). - Ex-smokers: Ever smokers who had not smoked within 12 months (US) or 6 months (Basque Country). - Current smokers: Ever smokers who smoked in last 30 days. - Ever drinkers: Individuals who ever drank alcohol. - Ex-drinker: Ever drinkers who had not drank in last 12 months. - Current drinker: Ever drinkers who drank in last 12 months.	- A significant association was reported between current smoking and current drinking. - Among ever drinkers, achieving smoking cessation was significantly associated with quitting alcohol consumption among males and females living in Basque Country during 1992, African-American males and females living in Basque Country during 1992, and African-American females living in the US during 1996.	- Smoking and alcohol consumption were dichotomous variables. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 2: Cross-Sectional Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Finnegan et al., 1985	- 35 post-coronary patients. - The sample was comprised of 86% men and a mean age of 56 years. - 31 patients experienced their first myocardial infarction, while 4 patients encountered an episode of angina severe enough to be hospitalized. - All patients had achieved at least one behavioural change.	- Interviews were conducted within 18 months of the patient's hospitalization. - Maintenance was calculated as the number of weeks of successful behaviour change divided by the number of weeks between the initiation of the behavioural change process and the administration of the interview. - Favourable changes in exercise were defined as participating in at least 10 minutes of exercise for a minimum of 3 times/week. - Positive changes in smoking were classified as a reduction of at least 50% in daily smoking.	- Maintaining a reduction in smoking behaviour was positively associated with maintaining an active lifestyle.	- Sample consisted exclusively of post-coronary patients and results may not generalize to general population. - Behaviour change was expressed as a percentage of the number of weeks a healthy behaviour was maintained. - Potential mediating cognitive-behavioural mechanisms were not assessed.
Garrett et al., 2004	- Stratified random sample of 9,675 health plan members. - 18 years of age or older as 46% were 35 to 54 years old. - Females represented 56%. - Majority were Caucasian (95.5%), married (69%) and had some college education (56%).	- Stages of change to quit smoking. - Stages of change for participating in moderate physical activity. - The guideline for physical activity was a minimum of 30 minutes of moderate physical activity on 5 or more days per week.	- People in the maintenance stage for physical activity were as likely to be in the precontemplation stage for smoking as they were to be in the maintenance stage. - Stages of change for smoking and physical activity were significant, but weakly related.	- Lack of generalizability. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 2: Cross-Sectional Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Keller et al., 2008	- A convenience sample of 1262 university students. - Students were recruited from various departments including Law (25%), Education (32%), and Medicine (43%). - Females represented 59% of the sample. - Mean age of the sample was 21 years old.	- Stages of change for vigorous exercise, smoking cessation, and binge drinking. - Vigorous exercise – exercising for a minimum of three times per week for at least 20 minutes. - Smoking – ever smoked cigarettes and number of cigarettes smoked per day. - Binge drinking – four and five alcoholic drinks for females and males, respectively.	- Significant correlations included exercise and smoking ($r = -0.09$), and binge drinking and smoking ($r = 0.35$). - Correlation between exercise and binge drinking ($r = 0.05$) was not significant.	- Sample consisted of university students which limits generalizability. - Validity of staging algorithms. May have produced stage misclassification. - Use of vigorous exercise underestimates additional intensities of exercise. - Potential mediating cognitive-behavioural mechanisms were not assessed.
King et al., 1996	- 332 male and female smokers employed at two workplaces. - Males comprised 62% of the sample. - Average age was 40 years old. - Caucasians made up 93.4% of the sample.	- Stages of change for exercise and smoking. - Regular exercise was defined as three times or more per week for 15 min or longer. - 5-item self-efficacy for exercise. - 6-item decisional balance measure for exercise. - Smoking abstinence self-efficacy scale. - 11-item decisional balance scale for smoking.	- Negative consequences of smoking was associated with positive benefits of physical activity. - Benefits of smoking was associated with the cons of physical activity. - Self-efficacy for refraining from smoking was associated with self-efficacy for exercising. - Smokers preparing to quit smoking demonstrated less confidence to exercise than smokers taking action to change their smoking habits. - Stages of change between health behaviours were not associated.	- Only smokers were enrolled limiting generalizability. - Different criteria to define the action stage for quitting smoking (cutting down on cigarettes or participating in a cessation program). - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 2: Cross-Sectional Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Lippke et al., 2012	Study 1: - Sample of 3,519 Hawaiian participants. - 60% were women - 18 to 91 years of age. - Average age of 46 years. - 33% of participants had a high school degree or less. Study 2: - 965 German speaking participants. - 66% were women. - Age range was 15 to 81 with an average age of 39 years. - 64% of the sample had post-secondary education. Study 3: - 310 diabetics. - 59% women. - Ages ranged from 18 to 75 years. - Average age was 44 years. - 75% of sample had post-secondary education.	- Stages of change for physical activity, non-smoking, healthy drinking, and reduced alcohol consumption.	Study 1: - Significant correlation between physical activity and non-smoking (r = 0.08). Study 2: - Correlation between physical activity and healthy drinking (r = 0.16) was significant. - Non-significant correlations were found between physical activity and non-smoking (r =0.01) and healthy drinking and non-smoking (r = -0.01) Study 3: - The correlation between physical activity and non-smoking (r = 0.21) was significant. - Non-significant correlations were observed between physical activity and reduced alcohol consumption (r = 0.06) as well as reduced alcohol consumption and non-smoking (r = 0.07). - Overall, there was evidence of a potential transfer effect among health behaviours of the same discipline.	- Potential mediating cognitive-behavioural mechanisms were not assessed. - In study 3, the sample consisted of diabetics limiting generalizability.

Table 2: Cross-Sectional Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Pirie et al., 2000	- 7,489 pregnant women from an HMO in two major cities. - Over 18 years old with an average age of 29.6 years. - 49% were college graduates. - Predominantly Caucasian. - Majority were married or cohabiting (94%). - 62% had full time employment.	- Alcohol consumption - # of drinks consumed currently and before pregnancy. - Alcohol quitters – consumed alcohol prior to pregnancy, but no consumption while pregnant. - Cigarette smoking assessed cigarette smoking in the past seven days (i.e. # of cigarettes per day and # cigarettes per day before pregnancy). - Cigarette quitters were individuals who made the transition from previously smoking prior to pregnancy to non-smoking in the past week during pregnancy.	- No association was observed between alcohol and cigarette smoking.	- Questions pertaining to alcohol use were imprecise (i.e. questions related to patterns of drinking or binge drinking would be preferred). - Results are not generalizable to the general population as pregnant women were evaluated. - Smoking behaviour and alcohol use were dichotomized. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 3: Critique of Cross-Sectional Studies Retrieved for a Systematic Review

Reference	Sample Size	Generalizability	Cognitive-Behavioural Mediating Mechanisms	Adequate Measurement of Health Behaviours
Boudreaux et al., 2003	☑	☒	☒	☑
Boyle et al., 1998	☑	☒	☒	☑
de Leon et al., 2007	☑	☑	☒	☒
Finnegan et al., 1985	☑	☒	☒	☒
Garrett et al., 2004	☑	☒	☒	☑
Keller et al., 2008	☑	☒	☒	☑
King et al., 1996	☑	☒	☒	☑
Lippke et al., 2012*	☑	☑	☒	☑
Pirie et al., 2000	☑	☒	☒	☒

☑ Article fulfills criterion; ☒ Article fails to fulfill criterion.

*Studies 1 and 2 fulfilled the criterion for generalizability. Study 3 did not satisfy the criterion for generalizability.

2.7.2 Systematic Review of Longitudinal Studies:

Fifteen observational longitudinal studies were retrieved for this systematic review. The recruited sample, behavioural measurements, reported findings, and the study limitations for each of these longitudinal studies are summarized in Table 4. Similar to the cross-sectional studies, these fifteen longitudinal studies were critiqued based upon sample size, generalizability, the analysis of potential mediating cognitive mechanisms, and the assessment of health behaviours. Furthermore, longitudinal studies were evaluated based upon the number of assessment intervals that were incorporated. The critique of longitudinal studies is summarized in Table 5.

Thirteen of the 15 longitudinal studies identified through this systematic review had demonstrated adequate sample sizes. Of the two studies that were unable to satisfy this criterion, Murray et al. (2002) acknowledged that sample size could have been a potential limitation of their analysis, while Perkins et al. (1993) had employed only a small sample of recent ex-smokers (n = 24) which may have compromised the findings of their study.

Three longitudinal studies had recruited samples that were representative of the general population (Laaksonen, Luoto, Helakorpi, & Uutela, 2002; Murray, Cribbie, Istvan, & Barnes, 2002; Shaw, Krause, Liang, & McGeever, 2011). The remaining studies had enrolled exclusively males (T. Gordon & Doyle, 1986), women (McDermott, Dobson, & Russell, 2004; Saules, et al., 2004), adolescences (Audrain-McGovern, et al., 2003; Terry-McElrath & O'Malley, 2011), college freshman (Dierker, et al., 2006; Jessor, Costa, Krueger, & Turbin, 2006), young adults (Breslau, et al., 1996), male twins (Carmelli, Swan, & Robinette, 1993), Japanese males (Nagaya, Yoshida, Takahashi, & Kawai, 2007), middle aged women (Perkins, et al., 1993) or daily smokers (Kahler, et al., 2009).

Each of the 15 longitudinal studies overlooked the assessment of self-efficacy, mastery, or additional cognitive mediating mechanisms within the interrelationship of health behaviours. In regards to the assessment of health behaviours, each of the longitudinal studies neglected to employ the Trans-Theoretical Model or any other established behavioural change theory to assess health behaviours. While studies could also fulfill this criterion by integrating continuous health behaviour variables, Murray et al. (2002)

and Dierker et al. (2006) were the only studies to incorporate this methodology and consequently fulfill the criterion for adequate measurement of health behaviours.

Finally, only seven studies had examined the interrelationship of health behaviours across more than two time periods (Audrain-McGovern, et al., 2003; Dierker, et al., 2006; Jessor, et al., 2006; Nagaya, et al., 2007; Saules, et al., 2004; Shaw, et al., 2011; Terry-McElrath & O'Malley, 2011). As the remaining eight studies only assessed health behaviours across one follow-up period, it is possible that changes among health behaviours may have occurred during the interim period particularly if the time interval between baseline and follow-up was of long duration (Emmons, Shadel, et al., 1999). Furthermore, the use of multiple cycles of data collection often improve the precision of parameter estimates (Rimm & Stampfer, 2004; D. Rogosa, Brandt, & Zimowski, 1982).

Table 4: Longitudinal Multiple Health Behavioural Change Studies

Reference	Sample	Measurements	Results	Limitations
Audrain-McGovern et al., 2003	- 978 high school adolescents attending five public high schools in northern Virginia. - Females represented 52% of the sample. - Racial distribution of the sample included 63% Caucasian, 12% Hispanic, 11% Asian, 8% African American, and 6% other.	- 4 waves of data were collected over a 4 year period; spring of the 9^{th} grade, fall and spring of the 10^{th} grade, and spring of the 11^{th} grade. - Smoking behaviour was represented by an ordered-categorical variable which included five responses. - Physical activity was measured by a continuous variable which was derived from frequency, duration, and intensity of physical activity.	- Baseline physical activity was not significantly associated with the rate of change in smoking. - Changes in physical activity demonstrated a 1.44 reduction in the odds of smoking progression. - A significant negative association was observed between initial smoking status and changes in physical activity. - Initial physical activity levels were positively associated with initial tobacco use.	- Lack of generalizability for older individuals. - Smoking behaviour was categorical. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Breslau et al., 1996	- Random sample of HMO members. - 1,007 young adults ranging from 21 to 30 years of age at baseline. Median age was 26 years old. - 62% were female. - Majority of individuals were Caucasians. - 45% were married. - College graduates represented 29%. - 979 individuals were interviewed at follow-up.	- 3½ year time period between baseline and follow-up. - Smokers were individuals who ever smoked daily for at least 1 month. - Smoking cessation was defined as quitting smoking at least 1 year before the last interview. - Alcohol dependence was defined as having 3 or more dependence symptoms.	- Smokers who abused alcohol were less likely to quit smoking compared to their counterparts who did not abuse alcohol. - Smokers who were no longer abusing alcohol were not significantly different from smokers with no history of alcoholism in regards to smoking cessation. - Smokers who continued to abuse alcohol were less likely to quit smoking compared to smokers who were in remission for alcohol. - Smoking cessation reduced the likelihood of subsequent remission of alcohol abuse. - No difference in alcohol remission was observed between those individuals who continued to smoke and those who quit smoking.	- Recall bias. - Lack of generalizability for older individuals. - Smoking and alcohol measures were not continuous. - Two time points were assessed over 3½ year period. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Carmelli et al., 1993	- A sample of twins from the NAS-NRC Twin Registry. - 5,510 adult male twins. - 40 to 50 years of age. - Married individuals represented 85 to 90%. - 48 to 53% were retired. - Individuals possessing diseases ranged from 11 to 16%.	- 16 year period from baseline to follow-up. - Individuals were classified into the following categories for smoking behaviour; continuing non-smokers, quitters, and continuing smokers. - Frequency and quantity of alcohol consumption was measured.	- No significant changes in alcohol consumption for continuing non-smokers, but a significant increase in consumption among quitters and continuing smokers. - Continuing smokers consumed significantly more alcohol than individuals who achieved smoking cessation.	- Not a random sample. Therefore selection bias may influence results. - Results may not be generalizable. - Only two time points over 16 years. - Potential mediating cognitive-behavioural mechanisms were not assessed.
Dierker et al., 2006	- 225 college freshman who had reported smoking and drinking on at least 10 occasions during their freshman year.	- Each week individuals reported their cigarette use and alcohol consumption for the previous 7 days. - Behaviours were assessed for 210 days which represented 30 weeks. - Smoking was represented by the number of cigarettes smoked per day, while alcohol consumption was assessed by the number of drinks an individual consumed per day.	- Majority of individuals reported positive correlations between smoking and alcohol consumption. Therefore, higher levels of smoking predicted greater levels of alcohol and vice versa. - Smoking less than 1 cigarette/day had a lower likelihood of a positive correlation between smoking and alcohol consumption. - Alcohol groupings demonstrated similar rates of positive correlations between smoking and alcohol consumption.	- Results may not be generalizable. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Gordon et al., 1986	- 1768 male civil service employees from New York State. - Males were 38 to 55 years of age.	- Two measurement periods 18 years apart. - Alcohol consumption was determined during a 30 day month. - Alcohol consumption was represented by a continuous and categorical variable.	- Non-significant correlation indicated that changes in alcohol consumption were not associated with changes in smoking behaviour.	- Only two time points over a 18 year period. - Sample consisted exclusively of males and results may not generalize to females. - Alcohol consumption appeared to be a categorical variable. - Potential mediating cognitive-behavioural mechanisms were not assessed.
Jessor et al., 2006	- Sample included 858 college freshman who had ever consumed alcohol during one of the three assessment periods. - At baseline, participants were predominantly male (56%) and White (87%).	- Three assessment periods over a 2 year span; fall 2002, spring 2003, and spring 2004. - Heavy episodic drinking was defined as the number of times an individual drank 5 or more drinks on any occasion. Responses were indicated on a 7-point scale. - Smoking was measured as the number of cigarettes smoked on an average day. Responses were presented on a 9-point scale.	- Changes in smoking behaviour were not associated with changes in heavy episodic drinking of alcohol.	- Not a random sample. Therefore selection bias may influence results. - Sample consisted of college freshman and results may not generalize to the general population. - Alcohol consumption and smoking were categorical variables. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Kahler et al., 2009	- 3,614 smokers from the International Tobacco Control Four Country (ITC-4) survey. - Smokers were recruited from Australia, Canada, the UK, and the US. - Smokers were 18 years of age or older. - Females represented 46.8% of the sample. - Average age was 41.9 years. - Nearly 96% of the sample were daily smokers.	- Waves 4 and 6 were analyzed from the ITC-4. - Alcohol use was measured by drinking frequency, number of drinks consumed, and frequency of heavy drinking over the past 12 months. - Drinking and heavy drinking frequency were categorized. - Weekly alcohol consumption was derived from the product of drinking frequency and number of drinks consumed. - Weekly alcohol consumption was categorized. - Categories were created to represent changes in alcohol consumption (drinking increased, unchanged, or decreased). - Smoking outcomes included attempting cessation and achieving a sustained cessation attempt. - Smoking status at the final assessment was classified into categories; no cessation attempts, made a cessation attempt but continued to smoke at wave 6, and quit smoking for a minimum of 6 months at wave 6.	- Consuming heavy amounts of alcohol more than once a week was associated with lower odds of attempting cessation as well as achieving smoking cessation for a minimum of 6 months at wave 6. - Smoking status was not associated with drinking status at the final follow-up. - Smoking cessation did not predict changes in alcohol consumption.	- Only two time points over 2 year period. - Sample consisted exclusively of daily smokers and results may not be generalizable. - Alcohol consumption and smoking variables appeared to be categorical variables. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Laaksonen et al., 2002	- 5081 Finnish adults from the general population. - 44% were males. - Age ranged between 20 to 64 years.	- Two assessment periods over 7 years. - Smoking (based on smoking history), alcohol use (weekly consumption), and physical activity (frequency of leisure-time physical activity based on a six point scale) were assessed. - Behaviours were dichotomized: smoking (for at least 1 year and within the last 2 days), physical inactivity (less than once a week), and high levels of alcohol (more than 10 and 4 units per week for males and females, respectively).	- In men, smoking cessation was associated with physical activity. - In men, initiating smoking was associated with physical inactivity. - Among females, adopting smoking was associated with an increase in alcohol use.	- Only two assessment periods over a 7 year period. - Health behaviours were represented by dichotomous variables. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
McDermott et al., 2004	- A sample of women from the Australian Longitudinal Study on Women's Health. - Three cohorts of Australian women were examined; 18-23 years of age, 45-50 years of age, and 70-75 years of age. - Sample consisted of 9,151 women. - Adopters of smoking represented 3% of the sample, whereas 6% and 4% of women were quitters and re-starters, respectively.	- Women were assessed in 1996 and 2000. - Adoption of smoking included individuals who had never smoked in 1996 but started smoking by 2000. - Quitters were individuals who were smoking in 1996, but achieved smoking cessation by 2000. - Re-starters were individuals who were ex-smokers in 1996 and re-started smoking in 2000. -Various categories were employed to classify binge drinking; no change, reduction, and increase.	- Those women whose binge drinking increased reported the greatest likelihood of adopting smoking. - An increase in binge drinking was also associated with a reduction in the likelihood of smoking cessation.	- Sample consisted exclusively of women and results may not generalize. - Health behaviours were represented by binary variables. - Only two assessment periods over a 4 year period. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Murray et al., 2002	- 344 adults from the general population participating in the Winnipeg Health and Drinking Survey. - Individuals reported smoking and drinking at one of the two waves. - Mean age of males and females was 38.9 and 37.9 years, respectively. - Unemployment among males and females was 10.1% and 8.4%, respectively. - The majority of individuals reported family incomes of at least $35,000. - 66.3% of males were married, while 59.6% of females were married. - Women had 12.4 years of education, whereas men had 12.6 years.	- Two measurement periods 2 years apart. - Smoking behaviour was measured as the number of cigarettes smoked per day. - Drinking behaviour was assessed as number of drinks per day and number of times an individual was drunk.	- Changes in alcohol consumption were not significantly related to changes in smoking and thus independent of one another.	- Only two assessment periods over a 2 year period. - Only individuals who smoked and drank were included in the analysis. - A larger sample size may have provided more confidence in the results. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Nagaya et al., 2007	- 750 healthy Japanese males - Subjects were retrospectively selected. - Sample 1 consisted of 98 abstaining smokers, 196 never smokers, and 196 persistent smokers. - The second sample recruited 52 relapsed smokers, 104 never smokers, and 104 persistent smokers.	- Annual questionnaire to obtain information on smoking and exercise. - Surveyed annually for 7 years. - Exercise was dichotomized (none vs any).	- Former smokers were as active as never smokers and more active than persistent smokers. - Relapsing smokers decreased their activity from baseline to follow-up. Relapse smokers became less active than never smokers and as inactive as persistent smokers.	- Sample included Japanese males and results may not generalize to other cultures. - Exercise was a dichotomous variable (none versus any), while smoking was a categorical variable. - Potential mediating cognitive-behavioural mechanisms were not assessed.
Perkins et al., 1993	- Participated in the Healthy Women Study. - Women aged 42 to 50 years of age with a mean of 48 years of age. - 61% were married. - Majority were Caucasian. - College graduates represented 36%. - 115 continuing smokers, 24 recent ex-smokers, 111 continuing ex-smokers, and 217 never smokers.	- Follow-up occurred approximately 3 years after baseline. - Physical activity was measured as the average expenditure of kcal per week within the past year and most recent week. - Alcohol intake was assessed by determining how many days beer, wine, or liquor was consumed as well as how much was consumed per day. - Smoking was determined by self-report and expired-air CO was analyzed. Number of cigarettes per day was reported.	- No significant differences between changes in smoking and changes in alcohol consumption. - Recent ex-smokers had significantly greater levels of weekly physical activity expenditure over the previous year. However, this increase was primarily due to 3 individuals. In the most recent week, physical activity was not different between recent ex-smokers and continuing smokers.	- Small sample size, particularly among recent ex-smokers. - Lack generalizability for men and younger individuals. - Only two time points over a 3 year period. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Saules et al., 2004	- Sample included 490 female precollege freshman at the University of Michigan. - Never smokers represented 374 individuals in the sample, while 52 and 64 women were categorized as early-onset smokers and late-onset smokers, respectively.	- Surveyed on three occasions; 1991, nine months later in 1992, and 1995. - Binge drinking referred to consecutively consuming at least 5 alcoholic beverages. - Never smokers were females who smoked less than twice in one's lifetime at all three time points. - Early-onset smokers were women who smoked in both 1991 and 1995. - Those classified as late-onset smokers were individuals who were never smokers in 1991 and became a smoker in 1995.	-Binge drinking was highest among those females who were early-onset smokers. - Late-onset smokers demonstrated the greatest increase in binge drinking between 1992 and 1995. By 1995, the rate of binge drinking among late-onset smokers resembled that of early-onset smokers. - Both early-onset and late-onset smokers reported a greater frequency of binge drinking than never smokers.	- Categorical responses were collected for smoking and binge drinking. - Results may not be generalizable as sample consisted exclusively of women. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Shaw et al., 2011	- The Americans' Changing Lives Survey was used for data analysis. - The sample included 3,617 adults. - This analysis recruited adults aged 24 and older at baseline. - 47% of the sample was male and the average age was 47 years. - Whites represented 79% of the sample. - Individuals had an average of 12 years of education. - At baseline, abstainers of alcohol represented 41% of the sample, while 50% and 9% of the sample were moderate and heavy drinkers, respectively.	- There were 4 assessment periods; 1986, 1989, 1994, and 2001-2002. - Alcohol consumption was the outcome variable. - Individuals were categorized on the basis of monthly alcohol consumption. - Heavy drinking was defined as a minimum of 60 and 30 drinks per month for males and females, respectively. - Moderate drinkers were individuals who drank alcohol, but did not fulfill the guidelines for heavy drinking. - Alcohol abstinence was defined as not consuming alcohol for a particular assessment period. - Smoking status was dichotomized as current smokers and non-smokers. - Leisure-time physical activity was represented by a 4-point scale.	- Non-smoking was significantly associated with a greater likelihood of abstinence from alcohol. - An inactive lifestyle was associated with a higher probability of alcohol abstinence.	- Categorical and dichotomized responses were collected for alcohol consumption and smoking, respectively. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 4: Longitudinal Multiple Health Behavioural Change Studies Continued

Reference	Sample	Measurements	Results	Limitations
Terry-McElrath et al., 2011	- Data from the Monitoring the Future Study (MTF) which consists of high school seniors. - 11,741 seniors were included in the analysis. - 48% of the sample was male, while Whites represented 72% of high school seniors.	- Class cohorts of high school seniors were initially assessed from 1986 to 2001. - Individuals participated in a total of 5 measurement periods occurring at the following ages; 18, 19/20, 21/22, 23/24, and 25/26. - Frequency of both alcohol consumption and smoking were measured on a 7-point scale. - Participation in sports, athletics, or exercising (PSAE) was assessed on a 5-point scale.	- Both average alcohol consumption and cigarette use increased until 21/22 years of age and then decreased. - PSAE demonstrated a decreasing trajectory throughout the course of the study. - Negative correlations were reported between the intercept and slope for PSAE, alcohol consumption, and smoking. - At 18 years of age, higher PSAE was correlated with higher alcohol consumption. - At age 18, higher PSAE was associated with lower tobacco use. - From 18 to 22 years of age, changes in PSAE and changes in alcohol were unrelated. However, from the age of 21/22 to 25/26, a positive correlation was reported. - An increase in PSAE was associated with a decrease in tobacco use.	- Results may not be generalizable as the sample consisted of high school seniors. - Health behaviour variables were categorical. - Potential mediating cognitive-behavioural mechanisms were not assessed.

Table 5: Critique of Longitudinal Studies Retrieved for a Systematic Review

Reference	Sample Size	Generalizability	Cognitive-Behavioural Mediating Mechanisms	Adequate Measurement of Health Behaviours	Multiple Assessment Intervals
Audrain-McGovern et al., 2003	☑	☒	☒	☒	☑
Breslau et al., 1996	☑	☒	☒	☒	☒
Carmelli et al., 1993	☑	☒	☒	☒	☒
Dierker et al., 2006	☑	☒	☒	☑	☑
Gordon et al., 1986	☑	☒	☒	☒	☒
Jessor et al., 2006	☑	☒	☒	☒	☑
Kahler et al., 2009	☑	☒	☒	☒	☒
Laaksonen et al., 2002	☑	☑	☒	☒	☒
McDermott et al., 2004	☑	☒	☒	☒	☒
Murray et al., 2002	☒	☑	☒	☑	☒
Nagaya et al., 2007	☑	☒	☒	☒	☑
Perkins et al., 1993	☒	☒	☒	☒	☒
Saules et al., 2004	☑	☒	☒	☒	☑
Shaw et al., 2011	☑	☑	☒	☒	☑
Terry-McElrath et al., 2011	☑	☒	☒	☒	☑

☑ Article fulfills criterion; ☒ Article fails to fulfill criterion.

Although experimental and quasi-experimental studies were excluded from this systematic review, they constitute the majority of research pertaining to multiple health behavioural change. Therefore their contribution to this discipline of research should be acknowledged. However, the focus of this systematic review and statistical analysis pertains to observational data. Consequently, reference to experimental and quasi-experimental findings throughout subsequent sections of this dissertation will be kept to a minimum. In the following sub-sections, co-variation between health behaviours is discussed. This discussion is predominantly based upon the findings of previous empirical studies that were retrieved for the systematic review.

2.7.3 Alcohol Consumption and Leisure-Time Physical Activity Energy Expenditure:

Evidence pertaining to the interrelationship between alcohol consumption and physical activity is sparse. This is unfortunate as excessive consumption is often associated with inactivity (Rosal, et al., 2000; Terry-McElrath & O'Malley, 2011). The association between alcohol consumption and physical activity has typically been evaluated by longitudinal study designs. The only exception, a cross-sectional study, found no significant association in motivational readiness between these two behaviours (Keller, et al., 2008).

To this point, the findings of longitudinal studies have been inconsistent. Although Laaksonen et al. (2002) was unable to observe concurrent behavioural changes between alcohol consumption and physical activity, evidence of co-variation has been reported by others (Shaw, et al., 2011; Terry-McElrath & O'Malley, 2011). Over an 8 year period, alcohol consumption and participation in sports, athletics or exercising (PSAE) were assessed as categorical variables; alcohol consumption (1 = no occasions, 2 = one to two, 3 = three to five, 4 = six to nine, 5 = ten to nineteen, 6 = twenty to thirty-nine, 7 = forty or more occasions) and PSAE (1 = never, 2 = a few times a year, 3 = once or twice a month, 4 = at least once a week, 5 = almost every day) (Terry-McElrath & O'Malley, 2011). From the ages of 18 to 21/22, changes in alcohol consumption were not significantly related to changes in PSAE (Terry-McElrath & O'Malley, 2011). However, from the ages of 21/22 to 25/26, a positive correlation was reported between behavioural changes

such that decreases in alcohol consumption were associated with decreases in PSAE (Terry-McElrath & O'Malley, 2011). These findings suggest that co-variation between alcohol consumption and leisure-time physical activity could be influenced by age.

Co-variation may not only be influenced by age, but by quantity of alcohol consumption. In a sample of 3,617 adults, alcohol abstinence was significantly associated with an inactive lifestyle (Shaw, et al., 2011). However, heavy drinking demonstrated no relationship with leisure-time physical activity (Shaw, et al., 2011).

If the effectiveness of rehabilitation programs is enhanced through the incorporation of physical activity programs, health professionals could initially concentrate their time and resources on changing physical activity levels before attempting to achieve abstinence from alcohol. Short-term physical activity interventions that are used in conjunction with alcohol treatment programs can enhance physical activity participation and fitness levels among alcoholics, reduce urges associated with alcohol use, and improve rates of alcohol abstinence (Gary & Guthrie, 1972; Sinyor, Brown, Rostant, & Seraganian, 1982; Ussher, Sampuran, Doshi, West, & Drummond, 2004). As individuals with alcoholism demonstrate an interest in participating in physical activity, alcohol treatment programs may provide a teachable moment; "naturally occurring life transitions or health events thought to motivate individuals to spontaneously adopt risk-reducing health behaviours" (McBride, et al., 2003, pg. 156).

2.7.4 Leisure-Time Physical Activity Energy Expenditure and Smoking:

Smokers who engage in multiple unhealthy behaviours often report heavier smoking, higher levels of nicotine dependence, as well as lower levels of self-efficacy for refraining from smoking (Butterfield, et al., 2004; Sherwood, et al., 2000). In fact, for every additional lifestyle risk factor that a smoker exhibits, the likelihood of nicotine dependence increases by 23% (Butterfield, et al., 2004). Since the engagement of additional healthy behaviours is associated with smoking fewer cigarettes per day, lower nicotine dependence, as well as higher levels of motivational readiness to quit smoking, health professionals may have more success in changing smoking behaviour through the adoption and maintenance of other health behaviours such as physical activity (Butterfield, et al., 2004).

One of the more commonly evaluated pairwise combinations of unhealthy behaviours involves physical inactivity and smoking. It is no surprise that these two risk factors co-exist as smokers are typically more sedentary (Rosal, et al., 2001) and less physically active compared to their non-smoking counterparts (Conway & Cronan, 1992; Perkins, et al., 1993). However, in recent years, evidence has suggested that not all smokers share this commonality as a modest to moderate proportion of smokers, 16 to 30%, participate in regular physical activity (W. K. deRuiter, et al., 2008; T. K. King, et al., 1996; Ward, et al., 2003). Furthermore, changes in physical fitness have been observed among smokers suggesting that smoking does not hinder or obstruct individuals from becoming more physically active (Cooper, Resor, Stoever, & Dubbert, 2007). The fact that smokers demonstrate the capability to participate in physical activity and that smoking does not limit an individual's ability to improve their physical fitness suggests that health professionals could include physical activity in the implementation of multiple behavioural change interventions (Cooper, et al., 2007). The recognition that smokers may express an interest in participating in regular physical activity before attempting to change their smoking behaviour may provide further support for the inclusion of physical activity as an adjunct in smoking cessation programs (Garrett, et al., 2004).

The association between physical activity and smoking cessation is complex as well as controversial. Some have suggested that behavioural changes between physical activity and smoking cessation are associated with each other (Finnegan & Suler, 1985; Keller, et al., 2008; T. K. King, et al., 1996; Laaksonen, et al., 2002; Terry-McElrath & O'Malley, 2011), while others have demonstrated that these two lifestyle behaviours are independent behaviours (Boudreaux, et al., 2003). Furthermore, while Audrain-McGovern et al. (2003) have suggested that physical activity inhibits smoking progression, others have suggested that smoking cessation could act as a potential gateway behaviour towards a physically active lifestyle (Nagaya, et al., 2007; Perkins, et al., 1993).

As behavioural changes in exercise and smoking share several similar cognitive mechanisms (T. K. King, et al., 1996), the adoption of a physically active lifestyle could prove to be an innovative and effective method for initiating healthy changes in smoking cessation (Costakis, et al., 1999). Evidence of this relationship is presented by King et al.

(1996) who evaluated aspects of the Trans-Theoretical Model. Although motivational readiness between smoking and exercise was not significantly associated, King et al. (1996) reported that smokers who perceived the benefits of smoking also perceived the negative consequences of physical activity. Conversely, those smokers who perceived the negative consequences of smoking also perceived the benefits of exercise. In regards to decisional balance across the stages of change for both exercise and smoking, King et al. (1996) observed few significant associations. King et al. (1996) found that smokers intending to adopt exercise within the next 6 months perceived the negative consequences of smoking to be significantly more important compared to their counterparts who had no intention of becoming physically active. No other significant associations for decisional balance were observed across the behavioural stages of change. As expected, progression through the stages of change for exercise and smoking resulted in significantly higher levels of self-efficacy, respectively. Similar to decisional balance, a significant correlation was observed for self-efficacy levels across lifestyle behaviours indicating that high levels of self-efficacy for refraining from smoking was associated with high levels of self-efficacy for participating in exercise (T. K. King, et al., 1996). Upon further examination of this cross behavioural relationship for self-efficacy, it was observed that smokers participating in exercise demonstrated higher levels of self-efficacy in their ability to refrain from smoking compared to those smokers who were preparing to exercise. Likewise, smokers who were taking action to refrain from smoking reported higher levels of self-efficacy to exercise than those smokers who were preparing to refrain from smoking (T. K. King, et al., 1996). Thus, smokers who were taking action for one health behaviour demonstrated higher levels of self-efficacy for the other behaviour. As decisional balance and self-efficacy demonstrated significant associations across exercise and smoking, King et al. (1996) concluded that the cognitive mechanisms between changes in exercise and changes in smoking were similar and thus one behaviour could potentially act as a gateway behaviour for the other.

In an attempt to replicate the findings reported by King et al. (1996), Boudreaux et al. (2003) examined the association between exercise and smoking among a sample of individuals attending primary care clinics. Although different samples were employed, the results were quite similar. Both studies observed that motivational readiness to

change smoking behaviour was not significantly related with readiness to change exercise behaviour. Furthermore, similarities were reported for decisional balance as those individuals with positive views of smoking typically had negative views of exercise (Boudreaux, et al., 2003). Conversely, those individuals with negative views of smoking were more likely to have positive views of exercise (Boudreaux, et al., 2003). In contrast to King et al. (1996), smokers who had a negative view of smoking also had a negative view of exercise (Boudreaux, et al., 2003). However, this difference could be attributed to the recruitment of a sample that possessed at least one chronic illness. Therefore, this sample may not have possessed the capability to participate in exercise and consequently may have led to negative opinions towards a physically active lifestyle (Boudreaux, et al., 2003). Similar results between studies were also demonstrated for self-efficacy such that individuals with greater confidence in quitting smoking also demonstrated greater confidence in maintaining regular exercise (Boudreaux, et al., 2003). However, these correlations were weak. Although Boudreaux et al. (2003) and King et al. (1996) reported nearly similar results, unlike King et al. (1996), Boudreaux et al. (2003) concluded that smoking and exercise appear to be independent of each other as the cognitive behavioural mechanisms were not associated or weakly related across behavioural relationships. The fact that cognitive behavioural mechanisms across health behaviours were not significantly associated may not necessarily denote that health behaviours are independent of one another. Several possible explanations may provide justification for the observed non-significant associations between cognitive mechanisms. First, individuals may demonstrate a tendency to cluster differently within the stages of change across several health behaviours. As such, individuals may require 6 months of planning to change smoking, but other health behaviours such as physical activity or dietary habits may require substantially less time before intentions to change occur (Garrett, et al., 2004). Secondly, individuals may progress through the stages of change in one of two ways; in a linear fashion advancing from one stage to the next or in a cyclical manner in which the individual progresses and regresses several times until behavioural change is achieved (Plotnikoff, Hotz, Birkett, & Courneya, 2001; J. O. Prochaska, DiClemente, & Norcross, 1992). Behavioural change is often considered a dynamic process and it is not uncommon for individuals to regress one or more stages

before successful behavioural change is accomplished (Hyman, Pavlik, Taylor, Goodrick, & Moye, 2007; Nigg, et al., 2002). Thirdly, some individuals could progress quickly through the stages of change, whereas others may opt to proceed at a much slower pace (Herrick, et al., 1997). Finally, individuals may choose to change multiple behaviours in a sequential rather than simultaneous manner as a simultaneous approach could be overwhelming (Berg, et al., 2012). If a sequential approach is chosen, one would not expect motivational readiness across health behaviours to be significantly associated.

One fundamental limitation shared in studies reported by King et al. (1996), Boudreaux et al. (2003), was the utilization of a cross-sectional study design. Cross-sectional study designs only provide a "snapshot" of the interrelationship of health behaviours at one point of time. Therefore, this type of study design possesses an inability to establish temporal sequences as well as develop behavioural trajectories. Longitudinal studies would be more suitable in determining and understanding co-variation of health behaviours as they possess the capability to track the course of health behaviours over multiple time intervals.

A significant association between physical activity and smoking was observed within a sample of 5,081 Finnish adult men and women (Laaksonen, et al., 2002). Over a 7 year time period, Laaksonen et al. (2002) observed that Finnish men achieving smoking cessation were more likely to increase physical activity levels compared to their counterparts who continued to participate in tobacco use. Therefore, positive changes in one health behaviour were associated with beneficial changes in the other behaviour. Further, Finnish men who initiated smoking also increased their levels of physical inactivity suggesting that a negative alteration in one behaviour was related to a negative modification in the other health behaviour. No association between physical activity and smoking reached statistical significance among Finnish women.

Terry-McElrath et al. (2011) examined co-variation between PSAE and tobacco use in a sample of high school seniors over an 8 year period. From the ages of 18 to 21/22, increases in PSAE were significantly correlated with a declining trend in tobacco use. An identical association was also observed from 21/22 to 25/26 years of age (Terry-McElrath & O'Malley, 2011). Consequently, co-variation between physical activity and tobacco use appears to exist among a sample of high school seniors.

In a sample of 750 Japanese men, Nagaya et al. (2007) evaluated the interrelationship of smoking cessation and smoking relapse on exercise behaviour. Both former smokers and smokers who had relapsed were matched with continuing and never smokers. Although former smokers increased their exercise participation from baseline to the final follow-up, this increase was not significant (Nagaya, et al., 2007). However, the reported increase in exercise participation among former smokers was significantly greater than the observed decrease in exercise participation experienced among current smokers (Nagaya, et al., 2007). Never and former smokers reported similar levels of exercise (Nagaya, et al., 2007). Relapsed smokers demonstrated a significant reduction in exercise levels between baseline and the final follow-up (Nagaya, et al., 2007). This significant reduction in exercise participation among relapsed smokers was significantly greater than that experienced by never and persistent smokers at the final follow-up (Nagaya, et al., 2007). These results suggest that health behaviours are interrelated such that smoking cessation can result in the enhancement of increased exercise participation (Nagaya, et al., 2007). Unfortunately, Nagaya et al. (2007) also demonstrated that the reverse was true as an unhealthy behavioural change can lead to the adoption and maintenance of an additional unhealthy behaviour (Nagaya, et al., 2007).

Using a longitudinal study design, Perkins et al. (1993) also concluded that smoking cessation may lead to additional favourable behavioural changes including the participation in physical activity. This conclusion was reached due to the fact that those smokers who recently achieved smoking cessation demonstrated significantly greater levels of energy expenditure during leisure-time physical activity compared to individuals who continued to smoke. However, upon further examination, Perkins et al. (1993) observed that this significant increase in energy expenditure was primarily a result of three individuals increasing their energy expenditure by a minimum of 4,000 kcals/week. The remaining smokers who achieved cessation only increased their energy expenditure by 233 kcals/week. After excluding these three individuals from the analysis, physical activity expenditure did not significantly differ between recent quitters and continuing smokers (Perkins, et al., 1993). These results were most likely influenced by a small sample of recent ex-smokers (n = 24).

While some researchers have elected to examine the association between physical activity and smoking cessation, others have chosen to evaluate physical activity as a potential harm reduction strategy for the progression of smoking. In one particular study it was concluded that the direct effect of changes in physical activity was associated with a 1.44 decrease in the likelihood of adolescences progressing to a higher intensity of smoking behaviour (Audrain-McGovern, et al., 2003). The findings presented by Audrain-McGovern et al. (2003) suggest that longitudinally, physical activity may not only be interrelated with smoking cessation but the prevention of progressing to a greater intensity of smoking.

To summarize, cross-sectional studies have provided conflicting evidence of whether an association exists between physical activity and smoking cessation (Boudreaux, et al., 2003; T. K. King, et al., 1996). However, longitudinal studies including Laaksonen et al. (2002), Audrain-McGovern et al. (2003), Nagaya et al. (2007), and Terry-McElrath et al. (2011) have suggested that a significant interrelationship exists such that changes in one behaviour influence changes in the other health behaviour. However, considering these longitudinal studies have incorporated several limitations including a lack of repeated assessments across time, the use of dichotomous or categorical dependent variables, and the exclusion of cognitive behavioural mechanisms within the statistical analysis, additional studies will be necessary to provide a better understanding of this potential interrelationship between physical activity and smoking.

2.7.5 Alcohol Consumption and Smoking:

Although the prevalence of individuals who participate in excessive alcohol consumption and smoking is less than 1% (Klein-Geltink, et al., 2006), these two behaviours demonstrate a tendency to co-exist (Schuit, et al., 2002) as well as a significant positive dose-response relationship (Torabi, Bailey, & Majd-Jabbari, 1993). It has been suggested that alcohol treatment programs which incorporate a smoking cessation component could have significant implications on the health of individuals who abuse alcohol (Ellingstad, Sobell, Sobell, Cleland, & Agrawal, 1999). Smokers with concurrent alcoholism are typically more responsive and may experience greater health benefits if interventions

provide simultaneous treatment for smoking cessation and alcohol abuse (Ellingstad, et al., 1999).

Similar to physical activity and smoking cessation, literature pertaining to the interrelationship between alcohol consumption and smoking is inconsistent. Several studies have shown no association between changes in alcohol consumption and smoking (T. Gordon & Doyle, 1986; Jessor, et al., 2006; Kahler, et al., 2009; Lippke, et al., 2012; Murray, et al., 2002; Perkins, et al., 1993; Pirie, et al., 2000), while others have provided evidence demonstrating that co-variation exists between these two behaviours (Breslau, et al., 1996; Carmelli, et al., 1993; Dierker, et al., 2006; Keller, et al., 2008; Laaksonen, et al., 2002; McDermott, et al., 2004; Saules, et al., 2004; Shaw, et al., 2011).

One example in which co-variation between alcohol consumption and smoking was established occurred in a sample of female pre-college freshman (Saules, et al., 2004). At baseline, Saules et al. (2004) found that individuals who initiated smoking at an earlier age demonstrated more frequent episodes of binge drinking compared to non-smokers and females who initiated smoking at an older age. However, throughout the course of the study, women who commenced smoking at a later age exhibited a rise in the frequency of binge drinking that was eventually similar to the rates of binge drinking as their counterparts who initiated smoking at an earlier age (Saules, et al., 2004). By the completion of the study, binge drinking rates among both early and late initiators of smoking were significantly higher compared to never smokers (Saules, et al., 2004). These findings suggest that initiating smoking is associated with an escalation in the frequency of binge drinking (Saules, et al., 2004).

Another example of co-variation between alcohol consumption and smoking was reported by McDermott et al. (2004). In this particular study, women who increased their binge drinking over a four year period reported the highest likelihood of adopting smoking (McDermott, et al., 2004). Unfavourable changes in alcohol consumption also demonstrated the ability to inhibit efforts in quitting smoking. In fact, women who increased their frequency of binge drinking reported the lowest odds in achieving smoking cessation (McDermott, et al., 2004). Once again, these findings provide evidence of a significant relationship between changes in alcohol consumption and changes in smoking behaviour.

Perhaps as important as the establishment of co-variation is the temporal sequence in which behavioural changes are administered. Breslau et al. (1996) examined the interrelationship of alcohol consumption and smoking within a sample of 1,007 young adults who were members of a Health Maintenance Organization (HMO). Compared to smokers with no history of alcoholism, smokers whose alcoholism was in remission had a similar likelihood of achieving smoking cessation, whereas smokers with alcoholism in the last year were 60% less likely to achieve smoking cessation (Breslau, et al., 1996). Smokers in remission for alcoholism were 3.62 times more likely to achieve smoking cessation compared to smokers who continued to drink alcohol excessively (Breslau, et al., 1996). Although treating alcoholism prior to smoking increased the likelihood of achieving smoking cessation, the reverse relationship was not observed by Breslau et al. (1996). The initial treatment of smoking reduced the odds of subsequent remission of alcoholism as similar rates of alcoholism remission was observed between alcoholics who continued to smoke and alcoholics who achieved smoking cessation (Breslau, et al., 1996). However, caution should be taken when interpreting the results presented by Breslau et al. (1996) as recall bias was a potential limitation of the study. Furthermore, smokers were categorized as those individuals who ever smoked daily for at least one month. Using this criterion to define smokers, individuals may have been smoking for only a short duration. If this is the case, achieving smoking cessation may have been easier compared to recruiting a sample with a longer history of smoking. These results suggest that treating alcoholism prior to treating smoking may enhance the success of public health interventions in changing these two behaviours (Breslau, et al., 1996). As individuals typically commence smoking prior to initiating alcoholism, individuals may experience more difficulty in achieving smoking cessation as they have maintained this unhealthy behaviour for a longer duration (Bobo, Gilchrist, Schilling, Noach, & Schinke, 1987).

An additional possibility in the interrelationship between alcohol consumption and smoking is that a positive behavioural change may yield a change that is deemed unfavourable. Carmelli et al. (1993) provide such an example. Among War World II Veteran Twins, smoking cessation was associated with a moderate increase in alcohol

consumption. It was suggested that the cues associated with initiating smoking may trigger an increase in the consumption of alcoholic beverages (Carmelli, et al., 1993).

The association between behavioural changes in alcohol consumption and smoking is complex. Some evidence suggests that changes in one behaviour may lead to changes in the other behaviour, whereas others have shown no association between the two behaviours. Likewise, the sequence in which behavioural changes should be administered is also uncertain. Further research is required in order to determine the true association between these two health behaviours. If smoking cessation produces beneficial results in alcohol consumption, then substance abuse programs may provide an opportunity to treat both behaviours simultaneously and thus enhance the effectiveness of public health programs (J. J. Prochaska, Delucchi, & Hall, 2004).

2.8 Limitations of Existing Multiple Health Behavioural Change Research:

After a critical review of the aforementioned observational studies, a number of limitations were identified that may have compromised the results of current literature. Again, these limitations are summarized in Tables 2 through 5. Study design is perhaps the most critical limitation of multiple health behavioural change research. The use of a cross-sectional study design is an important limitation as these studies are incapable of accounting for variations in behavioural change as well as establishing the temporal associations among behaviours. For example, it has been suggested that a non-significant or weak association between cognitive mechanisms that facilitate behavioural change denotes that health behaviours are independent of one another (Boudreaux, et al., 2003). If the stages of change between health behaviours are strongly associated, then individuals would be in similar stages of change across health behaviours (Garrett, et al., 2004). This would indicate that individuals utilize a simultaneous approach for changing multiple health behaviours. However, individuals may decide to change multiple health behaviours in a sequential manner. Therefore, one would not expect motivational readiness between health behaviours to be associated (W. C. Taylor, et al., 2004). Furthermore, as individuals progress through the stages of change, it is not uncommon for individuals to regress one or more stages on several occasions before successful behavioural change is achieved (Nigg, et al., 1999; O'Hea, et al., 2004; Plotnikoff, et al.,

2001). Cross-sectional studies would not have the capability to track such movements through the stages of change. Longitudinal studies would be more appropriate in examining trajectories of multiple health behaviours across time (Pronk, Peek, et al., 2004). Unfortunately, longitudinal studies that have evaluated the co-variation of multiple health behaviours have typically employed only one follow-up period (Breslau, et al., 1996; Carmelli, et al., 1993; T. Gordon & Doyle, 1986; Kahler, et al., 2009; Laaksonen, et al., 2002; McDermott, et al., 2004; Murray, et al., 2002; Perkins, et al., 1993). Longitudinal study designs that incorporate only two measurement periods are typically inadequate in examining individual trajectories as they provide only limited amounts of information. Although it is conceivable to model linear trajectories with two observations (D. Rogosa, et al., 1982; D. R. Rogosa & Willett, 1985; Satia, et al., 2004), others have suggested that more than two measurements are required to adequately fit a linear model (MacCallum, Kim, Malarkey, & Kiecolt-Glaser, 1997; Streiner, 2008). Consequently, such study designs may not be able to accurately depict the trajectory of health behaviours as precisely as using multiple time intervals. If the modelling of nonlinear growth trajectories is required, more than two measurements on the same individual will be necessary (Francis, Fletcher, Stuebing, Davidson, & Thompson, 1991). In any case, the accumulation of health behaviour information through multiple cycles of data collection enhances the precision of parameter estimates (Rimm & Stampfer, 2004; D. Rogosa, et al., 1982).

Other limitations that have been identified within previous literature include small sample sizes, lack of generalizability, the use of dichotomous or categorical variables, and an inability to assess potential cognitive mediating mechanisms. Small sample sizes or small sample subgroups have been reported in previous studies (Murray, et al., 2002; Perkins, et al., 1993). Studies that recruit small sample sizes or subgroups may have difficulty in observing true associations between outcome variables.

The generalizability of findings is another important limitation that needs to be addressed in future studies. Studies that recruit exclusively males (Carmelli, et al., 1993; T. Gordon & Doyle, 1986; Nagaya, et al., 2007), females (McDermott, et al., 2004; Perkins, et al., 1993; Saules, et al., 2004), adolescences (Audrain-McGovern, et al., 2003; Terry-McElrath & O'Malley, 2011), college freshman (Dierker, et al., 2006; Jessor, et al.,

2006), certain age groups (Breslau, et al., 1996), individuals diagnosed with chronic conditions (Boudreaux, et al., 2003; Boyle, et al., 1998; Finnegan & Suler, 1985), university students (Keller, et al., 2008), pregnant women (Pirie, et al., 2000), smokers (Kahler, et al., 2009), or only healthy individuals from specific cultures (Nagaya, et al., 2007) may have difficulty generalizing results back to the general population. Only two cross-sectional (De Leon, et al., 2007; Garrett, et al., 2004) and three longitudinal studies (Laaksonen, et al., 2002; Murray, et al., 2002; Shaw, et al., 2011) have employed a sample that was representative back to the general population.

An additional limitation of multiple health behavioural change research is the utilization of dichotomous or categorical independent and/or dependent variables among both cross-sectional (De Leon, et al., 2007; Pirie, et al., 2000) and longitudinal studies (Audrain-McGovern, et al., 2003; Breslau, et al., 1996; Carmelli, et al., 1993; T. Gordon & Doyle, 1986; Jessor, et al., 2006; Kahler, et al., 2009; Laaksonen, et al., 2002; McDermott, et al., 2004; Nagaya, et al., 2007; Perkins, et al., 1993; Saules, et al., 2004; Shaw, et al., 2011; Terry-McElrath & O'Malley, 2011). As previously mentioned, the use of dichotomous or categorical variables indicates whether individuals meet the recommended guidelines for a particular behaviour based upon a specific cut-off point. If any changes are made for a particular behaviour, these changes would go unnoticed unless individuals were to surpass the designated cut-off point. For this reason, the use of continuous health behaviours could be more appropriate as such variables are not restricted by specific criteria or cut-off points. These variables are more sensitive to behavioural changes compared to their dichotomous or categorical counterparts.

Finally, previous research, both cross-sectional (Boudreaux, et al., 2003; Boyle, et al., 1998; De Leon, et al., 2007; Finnegan & Suler, 1985; Garrett, et al., 2004; Keller, et al., 2008; T. K. King, et al., 1996; Lippke, et al., 2012; Pirie, et al., 2000) and longitudinal studies (Audrain-McGovern, et al., 2003; Breslau, et al., 1996; Carmelli, et al., 1993; Dierker, et al., 2006; T. Gordon & Doyle, 1986; Jessor, et al., 2006; Kahler, et al., 2009; Laaksonen, et al., 2002; McDermott, et al., 2004; Murray, et al., 2002; Nagaya, et al., 2007; Perkins, et al., 1993; Saules, et al., 2004; Shaw, et al., 2011; Terry-McElrath & O'Malley, 2011), have neglected to assess mediating cognitive-behavioural mechanisms in the evaluation of multiple behavioural change. Identifying cognitive mechanisms

which promote the adoption and maintenance of multiple behavioural change is essential (J. J. Prochaska & Sallis, 2004). It is these mechanisms that can be targeted by public health programs to facilitate behavioural changes. Therefore, these mechanisms should be included when examining co-variation between behaviours.

While this systematic review presents substantial evidence of co-variation between health behaviours, it is important to acknowledge the limitations associated with this systematic review. Publication bias could be a concern as this review exclusively retrieved articles that were peer-reviewed and excluded qualitative study designs, dissertations, conference abstracts, and gray literature. Furthermore, restricting the search to English language publications and the use of one electronic database may have also contributed to publication bias. Systematic reviews will often assess two important concepts; the quality of measures utilized and the ability to control for confounding variables. The use of invalid and unreliable measures may bias the findings of the study, whereas failing to consider confounding variables may produce a spurious relationship. These two concepts were not examined in this critique of articles. Lastly, this systematic review focused specifically on co-variation within adults. Studies that sampled children were excluded from this systematic review.

2.9 Summary:

Although multiple health behaviour research appears to represent an opportunity to facilitate in the prevention of chronic diseases (L. Gordon, et al., 2007), there are several questions that need to be addressed (Bock, et al., 1998; Clark, et al., 2005; Nigg, et al., 2002). Identifying the interrelationship of health behaviours could assist in the development of effective and cost-efficient public health interventions as programs could focus their resources on changing one health behaviour and indirectly facilitate the adoption and maintenance of additional health behaviours (Blakely, et al., 2004; Costakis, et al., 1999; Nigg, et al., 1999; Tucker & Reicks, 2002). Furthermore, changing multiple health behaviours could have a substantially greater impact on the overall well-being of individuals compared to modifying a single health behaviour (Klein-Geltink, et al., 2006; Nigg, et al., 2002). In the past, it was suggested that additional research was necessary to acquire a greater understanding of co-variation of health behaviours (Ory, et

al., 2002). Although recent years has seen more empirical research dedicated towards the co-variation of multiple health behaviours, the existence of co-variation remains open for debate; particularly between alcohol consumption and smoking.

Previous literature has attempted to examine the interrelationship of multiple health behavioural change. Unfortunately, these studies have incorporated several methodological limitations including cross-sectional study designs, small sample sizes, an inability to generalize results back to the general population, the use of dichotomous or categorical outcome variables, and the incapability to assess the potential mediating effects of cognitive mechanisms that may promote the adoption and maintenance of multiple behavioural change. Furthermore, longitudinal studies have typically incorporated two assessment periods, baseline and follow-up, as opposed to several assessment intervals.

The current study will address these limitations by conducting a longitudinal multi-wave study design within a nationally representative population-based database. In an attempt to identify the slightest changes within health behaviours, the current study will assess continuous dependent variables as an alternative to dichotomous or categorical variables that have been reported in previous literature. Furthermore, the statistical analysis of the current study will assess the effects of a potential mediating cognitive mechanism; mastery. By addressing the concerns of previous literature, the current study will advance the understanding of the interrelationship of multiple health behaviours. Therefore, the primary objective of this longitudinal study is to evaluate the interrelationship of health behaviours within nationally representative sample. The secondary objective of this analysis is to examine whether the potential mediating effects of mastery facilitates changes between multiple health behaviours.

Chapter 3
Methodology

3.1 Introduction:

To address the weaknesses identified in the existing literature, a dataset that assesses lifestyle behaviours over multiple time intervals within a nationally representative sample is required. Conducted by Statistics Canada, the National Population Health Survey (NPHS) is a longitudinal survey utilized to collect detailed information pertaining to socio-demographic characteristics, health status, utilization of health services, determinants of health, and chronic conditions of the Canadian population across several time periods (Statistics Canada, 2008). Since its initiation in 1994/1995, the longitudinal NPHS has been employed to address a wide assortment of research questions including the identification of risk factors associated with back pain (Kopec, Sayre, & Esdaile, 2004), the relationship between major depression and chronic diseases (Patten, et al., 2008), the examination of health status and use of health care services of immigrants (Newbold, 2005), the investigation of factors that predict the initiation and continued adherence of mammography screening among older women (Bancej, Maxwell, Onysko, & Eliasziw, 2005), the effects that a reduction in cigarette taxation may have on smoking initiation among young adults (Zhang, Cohen, Ferrence, & Rehm, 2006) and the examination of various health behaviour trajectories across gender and educational achievement (Kwan, Cairney, Faulkner, & Pullenayegum, 2012).

One of the many objectives of the NPHS was to assist in the evaluation of individual trajectories of health determinants across time (Statistics Canada, 2008). With its longitudinal study design, large nationally representative sample of Canadians, and its assessment of health behaviours over multiple time intervals, the NPHS dataset appears to be an appropriate choice for addressing this research question.

Before discussing the study design and sampling frame of the NPHS, it is important to acknowledge the fundamental concepts of the longitudinal NPHS dataset. The NPHS is a panel study; a series of cross-sectional studies that collect self-reported information on the same individuals at multiple time intervals (Kelsey, Whittemore, Evans, & Thompson, 1996; Last, 2001). Unlike cross-sectional studies, in which measurements are

made at a single time point, panel studies allow researchers the opportunity to examine the trajectory of variables across time. Thus, researchers can investigate how changes in one variable influence changes in additional variables (Kelsey, et al., 1996).

One of the more difficult challenges of any longitudinal study is attrition (Lilienfeld & Stolley, 1994; Statistics Canada, 2008). Throughout the follow-up process, it is not unusual for individuals to drop out, move to another location, or die before data collection is completed. As the proportion of individuals who are unwilling or unable to participate in follow-up surveys increases, the challenges associated with missing data become a concern (Lilienfeld & Stolley, 1994). For example, multivariate statistics require complete data on all cases (Figueredo, McKnight, McKnight, & Sidani, 2000; Streiner, 2008). If any case possesses missing data, that case as well as any responses provided by that case is eliminated from the multivariate analysis (Figueredo, et al., 2000; Streiner, 2002). As a result, a substantial proportion of a sample could be excluded from any multivariate analysis if missing data is prevalent (Figueredo, et al., 2000). Furthermore, the exclusion of individuals assumes that information is missing completely at random, which is often not the case (S. C. Duncan & Duncan, 1994). Thus, attrition may create a bias such that individuals who continue to participate in the study are no longer representative of the population from which the sample was chosen (Streiner, 2008). Although the use of weights may assist in maintaining a representative sample, missing data can result in the exclusion of specific cases from any multivariate analysis and still create the possibility of an unrepresentative sample (Figueredo, et al., 2000). Attrition may also generate concerns regarding statistical power which is reduced when missing data occurs (Streiner, 2008).

Since attrition is expected to have a substantial influence on the findings of longitudinal studies, Statistics Canada had undertaken several strategies to minimize this concern. Firstly, the number of potential participants assigned to each interviewer, which was based upon prior interviewing experience, was limited in an attempt to avoid overburdening interviewers and provide sufficient follow-up of participants (Statistics Canada, 2008). In addition, interviewers were also trained in strategies for reducing the number of non-contacts. These strategies included making phone calls and visiting residences at various times of the day (Statistics Canada, 2008). Multiple call backs were

made among respondents that were difficult to contact (Statistics Canada, 2008). In an attempt to increase individual participation, interviews would take place at the convenience of the respondent. Among individuals who refused to participate, a letter was sent from the Regional Office to the respondent outlining the importance of participating in the NPHS (Statistics Canada, 2008). Senior interviewers or project supervisors would also attempt to persuade respondents to participate in the survey (Statistics Canada, 2008). Periodically, respondents were unable to be traced. In this case, interviewers utilized the last known address and telephone number of the respondent as well as the name and contact information of others who may know the location of the respondent (Statistics Canada, 2008). Cases that did not respond to being interviewed were followed up in subsequent cycles in the hope that they may participate in future cycles (Statistics Canada, 2008).

3.2 Study Design:

A detailed description of the longitudinal NPHS study design is presented elsewhere (Statistics Canada, 2008). Briefly, data collection for the first cycle began in 1994/1995 and has continued biennially for subsequent cycles. When completed, the NPHS will have conducted ten cycles of data collection. Recently, the NPHS has completed nine cycles. However, at the time of this analysis, only seven cycles of data collection were available. It is these seven cycles that will be the focus for the current statistical analysis (Statistics Canada, 2008). It's difficult to determine how the inclusion of cycles 8 and 9 may have influenced the findings of this study. Certainly, greater rates of attrition would be influential on the covariances and correlations. However, the extent to which these covariances and correlations would be altered is unforeseeable.

The NPHS target population included Canadians residing in households throughout ten provinces. Excluded from the sampling frame were individuals residing on Indian Reserves and Crown Lands, institutions, or isolated areas in Ontario and Quebec, as well as full-time members of the Canadian Forces Bases. Information pertaining to the residents of the Canadian territories was also not included in this dataset. Initially, the NPHS had targeted 19,600 households with a minimum of 1,200 households within each

province (Statistics Canada, 2008). At baseline, 17,276 Canadians were interviewed ranging in age between 0 and 102 years of age (Statistics Canada, 2008).

The NPHS utilized a stratified multi-stage study design which closely resembled that of the Labour Force Survey (Statistics Canada, 2008). In the first stage, with the exception of Quebec, provinces were divided into three types of regions: major urban centres, urban towns, and rural areas. In Quebec, four types of regions were formed: Montreal Census Metropolitan Area, regional capitals, small urban agglomerations, and a rural sector. Each area was stratified based upon geographic and/or socio-economic characteristics. The first stage of the study design was completed once clusters from each stratum were selected using a Probability Proportional to Size sample (Statistics Canada, 2008). During the second stage of sample selection, households were chosen from an established dwelling list that was developed for each specified cluster. From each chosen household, one individual was randomly selected as the longitudinal respondent (Statistics Canada, 2008).

Randomly selecting one individual from each household may have resulted in a tendency within the survey to under-represent individuals residing in larger households, parents and children, whereas individuals living in smaller dwellings, single people and the elderly, would typically be over-represented (Statistics Canada, 2008). In an attempt to increase the representation of parents and children, the NPHS had incorporated a rejective method whereby screened households in which all members were of 25 years of age or more were eligible to be rejected, dropped from the survey, and replaced by another household (Statistics Canada, 2008).

For the first seven cycles, at least 95% of respondent interviews were conducted over the telephone (Statistics Canada, 2008). Telephone interviews were complemented by using computer-assisted interviewing. Face-to-face interviews were conducted under specific circumstances; the respondent did not own a telephone, if the respondent resided in an institution, if respondent had requested a face-to-face interview, or if the interviewer had visited the respondent's household while attempting to locate them (Statistics Canada, 2008). Proxy interviews were permitted among respondents 12 years of age or more who were suffering from illness and/or injuries (Statistics Canada, 2008). In the case of

respondents who were less than 12 years of age, interviews were conducted by proxy (Statistics Canada, 2008). Informed consent was obtained from all participants.

Once the interviewing process was completed, the first cycle of the longitudinal NPHS sample consisted of 17,276 Canadians (Statistics Canada, 2008). Table 6 presents the provincial sample size of the longitudinal NPHS for cycle 1 as well as the number of individuals providing full responses from cycle 1 through cycle 7. A total of 10,992 individuals had provided full responses for all seven cycles of the longitudinal NPHS (Statistics Canada, 2008). Providing a full response for the longitudinal NPHS denoted that individuals were assigned a status of either completing the survey, deceased, or institutionalized (Statistics Canada, 2008). Individuals were classified as a non-response if they had only partially completed the survey or if they had not responded to the survey. As expected, due to attrition, the sample size of the NPHS survey has gradually decreased with the passage of time. Throughout the NPHS, the most common sources of attrition resulted from non-response in the form of refusal to answer or unable to locate (Statistics Canada, 2008). After completing seven cycles of data collection, the cumulative attrition rate is approximately 36% (Statistics Canada, 2008).

Table 6: Characteristics of the NPHS by Province

Province	Sample Size in Cycle 1	Number of Canadians Providing Full Responses in Cycle 1 to Cycle 7
Newfoundland	1,082	746
Prince Edward Island	1,037	719
Nova Scotia	1,085	704
New Brunswick	1,125	728
Quebec	3,000	1,890
Ontario	4,307	2,546
Manitoba	1,205	805
Saskatchewan	1,168	824
Alberta	1,544	979
British Columbia	1,723	1,051
Total	**17,276**	**10,992**

In an attempt to attain estimates from a sample that was representative of the general population, sampling weights were incorporated into the longitudinal survey. The

longitudinal square weights are based upon several variables including province of residence, age, and gender. With the completion of each NPHS cycle, the longitudinal weights have been re-calculated to reflect the characteristics of the Canadian sample at 1994/1995 (Statistics Canada, 2008).

The longitudinal NPHS microdata is stored at Research Data Centres (RDC) within Canadian universities throughout the country. The RDC program is managed by Statistics Canada and the Social Sciences and Humanities Research Council (SSHRC) (Statistics Canada, 2008). In order to gain access to the NPHS, researchers must submit a research proposal to SSHRC outlining the title of the project, rationale and objectives of the study, proposed data analysis and software requirements, data requirements, and the expected project start and completion dates (Statistics Canada, 2008). Once access to the RDC is granted, Statistics Canada performs an Enhanced Reliability Check on all members of the research project (Statistics Canada, 2008). Furthermore, researchers are required to complete security clearance forms and participate in an orientation session at the RDC (Statistics Canada, 2008). For any statistical analysis that takes place in the RDC, researchers must abide by specific policies put forth by Statistics Canada regarding confidentiality and the release of research output (Statistics Canada, 2008). These policies include the following: 1) detailed microdata may not leave the RDC, 2) research results must be examined by a RDC analyst before it can leave the RDC facility, and 3) all research output leaving the RDC facility must be subjected to a disclosure analysis (Statistics Canada, 2008). A disclosure request form provides the RDC analyst with a description of the variables utilized as well as any new variables created by the researcher. The disclosure request also identifies databases and statistical software used during the analysis. It is these policies that ensure the confidentiality of information provided by the respondents who participated in the NPHS.

3.3 Modules of the National Population Health Survey:

The longitudinal NPHS consists of several modules of information. These modules, which are presented in Table 7, include health determinants, health status, medication and health care utilization, preventative health, self-care, social support, stress, and violence and personal safety (Statistics Canada, 2008). Alcohol consumption, physical activities,

and smoking were three modules of particular interest for this statistical analysis. The alcohol consumption module consisted of questions pertaining to the frequency and intensity of consumption as well as the reasoning for reducing one's intake of alcohol. Questions in the physical activities module pertain to the frequency, intensity, and duration of various modes of leisure-time physical activity. Respondent's energy expenditure was also assessed in the longitudinal NPHS (Statistics Canada, 2008). The smoking module of the NPHS included questions regarding the reasoning for respondents initiating and quitting smoking, current smoking status, motivational readiness to quit smoking, age that respondents initiated smoking, age in which smokers achieved cessation, the number of cigarettes smoked per day, the number of years that the respondent smoked, and the motive for smokers increasing or reducing their smoking behaviour (Statistics Canada, 2008).

Table 7: Modules of the National Population Health Survey

Alcohol Dependence	Alcohol Consumption	Administration of Survey	Attitudes Toward Parents	Chronic Conditions
Medication Use	Demographic and Household Variables	Dental Visits	Education	Emergency Services
Eye Examination	Family Medical History	Food Insecurity	Flu Shots	Geographic Identifiers
General Health	Health Care Utilization	Health Information	Health Status	HIV
Height and Weight	Injuries	Income	Insurance	Labour Force
Labour Status	Mental Health	Nutrition	Physical Activities	Physical Check-Up
Preventive Health	Restriction of Activities	Repetitive Strain	Road Safety	Rationality
Self-Care	Socio-Demographics	Sexual Health	Sleep	Smoking
Sample Identifiers	Social Support	Stress	Health Services	Tanning and UV Exposure
	Two-Week Disability	Violence and Personal Safety	Sample Weights	

3.4 Dependent Variables:

The health determinants that were evaluated in the current statistical analysis included alcohol consumption, leisure-time physical activity energy expenditure, and smoking behaviour. These three risk behaviours are among the most prevalent within the general population (Coups, et al., 2004; Fine, et al., 2004; Klein-Geltink, et al., 2006) and thus were chosen for this statistical analysis. Each of these three health determinants were derived by self-report and appear as continuous variables in the NPHS (Statistics Canada, 2008). For the purposes of this statistical analysis, these health behaviours were represented as continuous variables. Whether to conceptualize health behaviours as a dichotomous or continuous measurement is an issue that remains unanswered in multiple behaviour research (Nigg, et al., 2002). The use of continuous measures for health behaviours are typically more sensitive and provide more statistical power than dichotomous variables (Finney, Moyer, & Swearingen, 2003; J. J. Prochaska, Velicer, Nigg, & Prochaska, 2008). Thus, the probability of making a type II error is reduced through the use of continuous measures (Streiner, 2002). Furthermore, continuous measures place a greater emphasis on behavioural change as change is easier to recognize with continuous measures as opposed to dichotomous measures that require individuals to fulfill a specific criterion in order to reach a specific behavioural goal (J. J. Prochaska, Velicer, et al., 2008). In the past, alcohol consumption studies, particularly those evaluating physical health or drinking-related problems, have employed continuous outcomes including quantity of alcohol consumed (Finney, et al., 2003). Canadian surveillance agencies typically monitor leisure-time physical activity as a continuous measurement as well (Katzmarzyk & Tremblay, 2007). Duration, frequency, intensity, and mode are often utilized to create a continuous estimate of the average daily leisure-time physical activity energy expenditure (Katzmarzyk & Tremblay, 2007). Although continuous estimates may have difficulty in describing prevalence rates of leisure-time physical activity, continuous measures provide greater insight into the average level of physical activity within a population and a greater ability in tracking behavioural changes compared to using a dichotomous estimate (Katzmarzyk & Tremblay, 2007). The number of cigarettes smoked on a daily basis is an essential consideration in the monitoring of tobacco use (Mills, Stephens, & Wilkins, 1994). Assessing reductions in

tobacco use is worthwhile as it is associated with one's intentions to quit (Cunningham & Selby, 2010; Leatherdale & Shields, 2009) as well as the probability of achieving smoking cessation (Hughes & Carpenter, 2006; Hymowitz, et al., 1997; McDermott, Dobson, & Owen, 2008).

3.4.1 Alcohol Consumption:

Alcohol consumption was assessed by the respondent's average daily intake. As presented in Table 8, baseline responses for average daily alcohol consumption ranged from 0 to 14 drinks (Statistics Canada, 2008). Average daily alcohol consumption reached a maximum of 20 drinks during cycle 4. As a derived variable, average daily alcohol consumption was calculated by summing the total number of drinks consumed on all days during the week prior to being interviewed and dividing that value by seven (Statistics Canada, 2008). This variable was calculated for those respondents who had at least one drink within the previous 12 months (Statistics Canada, 2008). Answering this question as "not applicable" were respondents residing in institutions, children, or individuals who had not consumed an alcoholic beverage in the previous 12 months (Statistics Canada, 2008). For this analysis, individuals who had not consumed an alcoholic beverage in the previous 12 months received a daily alcohol consumption value of 0. Individuals whose response to daily alcohol consumption was "not applicable" or "not stated" were considered to have missing data. Moore et al. (2005) had employed a nearly similar continuous measure for alcohol consumption.

One dilemma with assessing alcohol consumption as a continuous variable is the fact that an increasing trend may not necessarily be indicative of an unhealthy behaviour. In fact, individuals may choose to increase their consumption of alcoholic beverages as a preventive measure against cardiovascular disease (Ronksley, Brien, Turner, Mukamal, & Ghali, 2011). Perhaps a more appropriate indicator of alcohol consumption would be the frequency in which one engages in binge drinking. Since binge drinking is recognized as an unhealthy behaviour, the use of binge drinking as an outcome would remove any ambiguity associated with measuring and interpreting the behavioural trajectory of alcohol consumption. Unfortunately, in six of the seven cycles, binge drinking was assessed as a categorical variable in which responses included the

following: never, less than once a month, once a month, two to three times a month, once a week, or more than once a week. The use of continuous variables is considered a novel or unique approach in representing health behaviours as it has only been adopted by a small minority of studies (Dierker, et al., 2006; Murray, et al., 2002). Therefore this study elected to exclude the use of a categorical binge drinking measure in favour of the continuous alcohol consumption indicator.

Table 8: Summary of Questions and Categories in the Alcohol Consumption Module at Baseline

Description of Question	Categories/Coding						
Drank Alcohol in Past 12 Months	Yes	No					
Frequency of Drinking Alcohol	<1/mth	1/mth	2-3/mth	1/wk	2-3/wk	4-6/wk	Everyday
Frequency of Having 5 or More Drinks	0-366						
Drank Alcohol In Past Week	Yes	No					
Ever Had a Drink	Yes	No					
Regularly Drank More Than 12 Drinks a Week	Yes	No					
Reason Reduced Drinking – Dieting, Getting Older, Pregnancy, etc	Yes	No					
Average Daily Alcohol Consumption	0-14						
Type of Drinker	Regular Drinker	Occasional Drinker	Non-Drinker Now	Never Drinker			
Weekly Alcohol Consumption	0-99						

3.4.2 Leisure-Time Physical Activity Energy Expenditure:

Physical activity refers to "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen, et al., 1985, pg. 126). Physical activity may include occupational, sports, conditioning, as well as household activities (Caspersen, et al., 1985). Leisure is one form of physical activity. Leisure denotes "unobligated or discretionary time – the free time that remains after the demands of work, maintenance, and family and social obligations have been met" (Wankel & Sefton, 1992, pg. 155). For the purposes of this analysis, leisure-time physical activity levels were assessed by average daily leisure-time energy expenditure within the past three months. As observed in Table 9, energy expenditure ranged from 0 to 35.2 kcal/kg/day at baseline and reached a maximum of 72.2 kcal/kg/day during cycle 6 (Statistics Canada, 2008). Energy expenditure for each mode of leisure-time physical activity was derived by estimating the average duration in hours of activity, the frequency of engagement over the previous 12 months, as well as the metabolic equivalent value characterized as kilocalories (kcals) utilized per kilogram (kg) per hour (Statistics Canada, 2008). One metabolic equivalent represents the amount of energy an adult expends while in a sitting position. The product of these three measurements was divided by 365 to obtain the daily energy expenditure for each mode of leisure-time activity (Statistics Canada, 2008). Energy expenditure for each mode of leisure-time activity was summed to obtain overall daily energy expenditure (Statistics Canada, 2008). With respect to criterion validity, total energy expenditure has demonstrated modest agreement with estimated VO_{2max} ($r = 0.36$) (Craig, Russell, & Cameron, 2002). For this analysis, individuals whose energy expenditure could not be calculated due to responses of "not applicable" or "not stated" were considered to have missing data.

Table 9: Summary of Questions and Categories in the Physical Activities Module at Baseline

Description of Question	Categories/Coding			
Activity in Last 3 Months – Walking, Swimming, Ice Hockey, etc	Yes	No		
Number of Times Participated – Walking, Swimming, Ice Hockey, etc	1-600			
Time Spent – Walking, Swimming, Ice Hockey, etc	1 to 15 min	16 to 30 min	31 to 60 min	More Than One Hour
Level of Physical Activity for Usual Day	Usually Sit and Don't Walk Much	Stand or Walk Quite A Lot	Usually Lift or Carry Light Loads	Do Heavy Work or Carry Very Heavy Loads
Daily Energy Expenditure	0	0.1-35.2		
Participation in Daily Physical Activity Lasting >15 Min.	Daily	Not Daily		
Monthly Frequency of Physical Activity Lasting >15 Min.	0	1-251		
Frequency of All Physical Activity Lasting >15 Min.	Regular	Occasional	Infrequent	
Participant in Leisure Physical Activity	Participant	Non-Participant		
Physical Activity Index	Active	Moderate	Inactive	

3.4.3 Smoking:

The number of cigarettes smoked per day was used to indicate smoking behaviour among Canadians who were identified as either current daily or occasional smokers (Statistics Canada, 2008). Among current smokers, the number of cigarettes smoked per day was assessed at every cycle of the NPHS. However, it was not until the third cycle of data collection that Statistics Canada began to assess tobacco use among occasional smokers. Responses for current daily smokers at baseline ranged from 1 to 99 (see Table 10), while responses for occasional smokers at the third cycle ranged from 1 to 55 (Statistics Canada, 2008). The number of cigarettes smoked per day was assessed for each smoker unless one of the following responses was provided; "not applicable", "don't know", or "not stated". Data was considered missing if any one of the aforementioned responses was provided by current daily or occasional smokers.

It was also necessary for this analysis to include those respondents who were non-smokers as these individuals may initiate smoking or achieve cessation in subsequent cycles. Therefore, those individuals who identified their smoking status as "not at all" and responded "not applicable" for the number of cigarettes smoked each day were assigned a value of 0 for the number of cigarettes smoked per day.

Table 10: Summary of Questions and Categories in the Smoking Module at Baseline

Description of Question	Categories/Coding					
Reason for Starting Smoking	Smoked at Last Interview	Family/Friends Smoke	Everyone Around Me Smokes	To Be "Cool"	Curiosity	Stress
	Started Again After Trying To Quit	Cost	To Control Weight	Other		
Reason for Smoking Less	Did Not Cut Down	Trying To Quit	Affected Physical Health	Cost	Social/Family Pressures	Athletic Activities
	Pregnancy	Smoking Restrictions	Doctor's Advice	Effect of Second-Hand Smoke On Others	Other	
Reason for Smoking More	Haven't Increased	Family/Friends Smoke	Everyone Around Me Smokes	To Be "Cool"	Curiosity	Stress
	Increased After Trying To Quit/Reduce	To Control Weight	Other			
Current Smoking Status	Daily	Occasionally	Not at all			
When First Cigarette Smoked After Waking Up	Within 5 Minutes	6 to 30 Minutes After Waking	31 to 60 Minutes After Waking	More Than 60 Minutes After Waking		
Tried Quitting Smoking	Yes	No				
Number of Times Tried to Quit Smoking	1-25					
Considering Quitting Smoking in the Next 30 Days	Yes	No				

Table 10: Summary of Questions and Categories in the Smoking Module at Baseline Continued

Description of Question	Categories/Coding					
Considering Quitting Smoking in the Next 6 Months	Yes	No				
Smoking Restrictions in Work Place	Restricted Completely	Allowed in Designated Areas	Restricted Only in Certain Places	Not Restricted at all		
Age Started Smoking Daily	5-81					
Number of Cigarettes Smoked Each Day	1-99					
Number of Years That Respondent Smoked	0-77					
Ever Smoked Daily	Yes	No				
Age Stopped Smoking Daily – Former Daily Smoker	10-90					
Reason for Quitting Smoking	Never Smoked	Didn't Smoke at Last Interview	Affected Physical Health	Cost	Social/Family Pressures	Athletic Activities
	Pregnancy	Smoking Restrictions	Doctor's Advice	Effect of Second-Hand Smoke on Others	Other	
Type of Smoker	Daily Smoker	Occasional Smoker (Former Daily Smoker)	Always an Occasional Smoker	Former Daily Smoker	Former Occasional Smoker	Never Smoked

These three variables, average daily alcohol consumption, daily leisure-time physical activity energy expenditure, and number of cigarettes smoked per day, were used to represent health behaviours for this analysis as they share similar units of measurement; daily basis. Similar units of measurement between multiple health behaviours are essential for interpretation purposes (Nigg, et al., 2002).

3.5 Independent Variables:

As mentioned in the preceding section, continuous variables were used to represent alcohol consumption, leisure-time physical activity energy expenditure, and smoking. In addition to these lifestyle variables, independent variables included demographic characteristics as well as body mass index (BMI). In previous literature, such characteristics have been shown to be associated with the possession of multiple health behaviours (Fine, et al., 2004; Laaksonen, et al., 2003; Li, et al., 2009; Rosal, et al., 2001) and therefore should be accounted for in each of the growth curve models. Demographic variables included gender (male and female), age of respondent (in years), marital status (married/common-law, single, and formerly married), education (less than secondary school graduation, secondary school graduation, some post-secondary schooling, and post-secondary graduation), and income adequacy (lowest income, lower middle income, upper middle income, and highest income) (Statistics Canada, 2008). Formerly married referred to individuals who were widowed, separated, or divorced. Education was based upon the highest level of education attained by the respondent (Statistics Canada, 2008). Income adequacy was classified according to the total household income and adjusted for the number of individuals residing in the household (Statistics Canada, 2008). Others have used comparable criteria in assessing marital status (W. K. deRuiter, et al., 2008; Kopec, et al., 2004), education (W. K. deRuiter, et al., 2008; Newbold, 2005; Zhang, et al., 2006), and income adequacy (W. K. deRuiter, et al., 2008; Kopec, et al., 2004; Newbold, 2005). Body mass index, which was assessed for all respondents excluding pregnant women, was calculated as weight in kilograms divided by squared height in meters (Statistics Canada, 2008).

The inclusion of the aforementioned independent variables in the current analysis was essential as they are often associated with the clustering of unhealthy behaviours

(Berrigan, et al., 2003; Fine, et al., 2004; Laaksonen, et al., 2003; Prattala, et al., 1994; Rosal, et al., 2001). Furthermore, these aforementioned independent variables are associated with alcohol consumption (Eng, Kawachi, Fitzmaurice, & Rimm, 2005; Moore, et al., 2005), excessive alcohol consumption (Karlamangla, Zhou, Reuben, Greendale, & Moore, 2006), leisure-time physical activity (Craig, Russell, Cameron, & Bauman, 2004; Eng, et al., 2005; Steffen, et al., 2006), and smoking behaviour (Eng, et al., 2005; Hyland, et al., 2004; Hymowitz, et al., 1997; C. W. Lee & Kahende, 2007).

3.6 Mediating Variable:

Mastery, a derived variable in the longitudinal NPHS, was based upon the work of Pearlin and Schooler (1978). A respondent's mastery score was assessed by 7-items (Pearlin & Schooler, 1978). Each of these 7-items, which are identified in Table 11, were measured on a 5-point scale. Possible responses included "strongly agree", "agree", "neither agree nor disagree", "disagree", or "strongly disagree" (Pearlin & Schooler, 1978). Scores for the final two items needed to be reversed before a mastery score could be calculated. Mastery scores, which were obtained through the summation of these 7-items, ranged from 0 to 28 with higher scores denoting an enhanced sense of mastery (Statistics Canada, 2008). Unfortunately, the mastery scale was not conducted within cycles 2 and 3 of the longitudinal NPHS and thus mastery scores were not calculated for these two cycles. Considering that this analysis utilized latent growth curve modelling, these missing mastery scores were not a concern as growth curve analysis is an appropriate statistical procedure for dealing with missing data (Streiner, 2002, 2008). Furthermore, according to Streiner (2008), only three data points are necessary to fit a regression line. Although others have suggested a minimum of four to five repeated measures to model linear change (MacCallum, et al., 1997), fulfilling the criteria put forth by Streiner (2008) and MacCallum et al. (1997) was not problematic as 70 and 60% of individuals had provided a minimum of three and four mastery scores, respectively.

Table 11: Items for Measuring Mastery

Number	Items
1	I Have Little Control Over The Things That Happen To Me.
2	There is Really No Way I Can Solve Some of The Problems I Have.
3	There is Little I Can Do To Change Many of The Important Things In My Life.
4	I Often Feel Helpless in Dealing With The Problems of Life.
5	Sometimes I Feel That I'm Being Pushed Around in Life.
6	What Happens To Me In The Future Mostly Depends On Me.
7	I Can Do Just About Anything I Really Set My Mind To Do.

3.7 Longitudinal Statistical Analysis Techniques:

Various statistical techniques have been employed to analyze longitudinal datasets. The difference score is perhaps the most instinctive method for measuring change between two time periods (Francis, et al., 1991; D. Rogosa, et al., 1982). The difference score subtracts an individual's follow-up score from their baseline score (Francis, et al., 1991; D. Rogosa, et al., 1982). Although, the difference score method is appropriate when two measurement periods are available, it only provides limited information pertaining to change and demonstrates an inability to model nonlinear growth (D. Rogosa, et al., 1982). More traditional statistical analysis of change for longitudinal data analysis includes repeated-measures analysis of variance (rANOVA) and multivariate repeated-measures analysis of variance (rMANOVA). However, these two methods have several limitations. Both techniques are susceptible to missing data as individuals with incomplete data are omitted from any statistical analysis (Gueorguieva & Krystal, 2004; Schafer & Olsen, 1998). As previously mentioned, the omission of individuals can result in a sample that is unrepresentative from the broader population. Furthermore, both rANOVA and rMANOVA require datasets to have similar measurement periods for each individual (Francis, et al., 1991; Gueorguieva & Krystal, 2004; Kristjansson, Kircher, & Webb, 2007). In addition, these statistical methods involve differences in group mean scores at each time period as opposed to individual scores (T. E. Duncan & Duncan, 2004; Stull, 2008). Group mean scores can conceal individual observations as well as individual change (Stull, 2008).

Other analytical techniques have been utilized for longitudinal data analysis. Two of these techniques, multivariable logistic regression modelling (Kopec, et al., 2004; Zhang,

et al., 2006) and generalized linear modelling (Bancej, et al., 2005) have been employed to analyze data from the NPHS. However, comparable to repeated-measures analysis of variance, these modeling techniques are also susceptible to missing data. Furthermore, these statistical techniques violate an important assumption of ordinary least squares. By nature, panel surveys collect repeated observations on the same individual across time. Ordinary least squares assumes that the error terms between observations is uncorrelated for each individual. However, in panel surveys, the opposite is demonstrated as the error term between observations are highly correlated for each individual. Although the parameter estimate is not affected by highly correlated error, the standard errors for such parameters are.

Latent growth curve models, also known as random coefficient regression models, mixed general linear models, or multilevel linear models, are a popular choice for evaluating change in continuous variables as such models offer several advantages compared to more traditional methods of analyzing longitudinal data (Collins, 2006; Francis, et al., 1991). Latent growth curve models not only possess the capability to generate growth parameters for each individual, but also provide growth parameter means, variances, and covariances (cov) for the entire group which permit researchers to examine inter-individual differences in trajectories across time (Curran, Harford, & Muthen, 1996; T. E. Duncan & Duncan, 2004; Stull, 2008; Willett & Sayer, 1996). Latent growth curve modelling is also known for its flexibility in modeling linear as well as nonlinear trajectories (Curran, et al., 1996; Llabre, Spitzer, Siegel, Saab, & Schneiderman, 2004; Stull, 2008; Willett & Sayer, 1996). In addition, latent growth curve modelling can incorporate numerous and unequally spaced assessment intervals (Francis, et al., 1991; Willett & Sayer, 1996). Incorporating numerous waves of data can increase the precision of parameter estimates and allows the opportunity to test more complex models (Francis, et al., 1991). Furthermore, latent growth curve modelling allows the estimation of parameters that are free of measurement error (Stull, 2008). Thus, parameter estimates are no longer reduced or susceptible to bias as a result of measurement error (Cheung & Lau, 2008; Llabre, et al., 2004). The ability to estimate parameters that are free from measurement error is an advantage over multi-level models (Stull, 2008). Growth curve models also possess the ability to evaluate the interrelationship of multiple latent

variables (MacCallum & Austin, 2000; Stull, 2008). This is one advantage that is not present in rANOVA, multi-level modelling, or mixed models (Stull, 2008). Finally, unlike multivariate analysis, growth curve modelling is an effective method for dealing with dropouts or missing data (Streiner, 2002, 2008). Growth curve modelling uses likelihood estimators to fit a trajectory. This trajectory is based upon all available observations (S. C. Duncan & Duncan, 1994; Francis, et al., 1991). Consequently, the exclusion of cases with missing data is less likely to occur and thus statistical power can be maintained.

Growth curve models fit growth trajectories by modelling the means of multiple observations on the same outcome across time (Collins, 2006; B. O. Muthen & Curran, 1997). Latent growth curve models depict growth as a two level model (B. O. Muthen & Curran, 1997). In the level 1 model, outcomes are determined by individual-specific growth parameters as well as time (Willett & Sayer, 1994, 1996). The individual linear growth trajectory is expressed as:

$$Y_{ti} = ß_{oi} + ß_{ti}\, x_{ti} + e_{ti}$$

The outcome, represented by *Y*, is calculated for an individual *i* at time *t* (Collins, 2006; Llabre, et al., 2004; Willett & Sayer, 1994). The data of the repeated observations are used to estimate two unobserved latent variables for each individual growth curve; the intercept and slope (Curran, et al., 1996; Curran, Stice, & Chassin, 1997; Mitchell, Kaufman, Beals, & Pathways of Choice and Healthy Ways Project Team, 2005; B. O. Muthen & Curran, 1997; Stull, 2008). The intercept, the initial status, and the slope, also known as the rate of change, are represented by $ß_{oi}$ and $ß_{ti}$, respectively (Collins, 2006; Llabre, et al., 2004; MacCallum, et al., 1997; Stoolmiller, 1994). The intercept, a constant, depicts the starting point of the trajectory at the first time period (Curran, et al., 1996; Stull, 2008; Willett & Sayer, 1996). In other words, the intercept illustrates the point at which the growth curve trajectory coincides with the vertical axis at the first measurement period (Stoolmiller, 1994). The slope represents change and illustrates the shape of the trajectory across each time period (Curran, et al., 1996; S. C. Duncan & Duncan, 1994; Willett & Sayer, 1994, 1996). The slope is defined as the "amount of vertical increase per unit of horizontal run of the growth curve" (S. C. Duncan & Duncan, 1994, pg. 320). These two parameters are of primary interest in latent growth curve

modelling as they characterize an individual's trajectory (Llabre, et al., 2004; Raudenbush, 2001) and are typically referred to as random effects as they can vary freely among individuals for any given trajectory (Collins, 2006; MacCallum, et al., 1997). The individual growth trajectory is also represented by x_{ti} and e_{ti}. The component x_{ti} denotes a measure of time, whether it be years, months, etc., for individual i at time t (Collins, 2006; MacCallum, et al., 1997; Stoolmiller, 1994). Finally, assumed to have values that are normally distributed with a mean of zero and a constant variance, e_{ti} is the deviation or difference between an individual's actual score (Y_{ti}) and their trajectory at a specific time (the repeated measures variable that is not explained by the latent variables) (Llabre, et al., 2004; Park & Schutz, 2005; Raudenbush, 2001). In other words, the error term represents the level 1 or within-person "noise" that influences the true growth parameter estimates (Willett & Sayer, 1996). This random error incorporates both measurement error and time specific error (Llabre, et al., 2004; Willett & Sayer, 1994). In latent growth curve modelling, the estimated latent variables are free from such random error.

Growth curve models also possess a level 2 equation. The level 2 equation, which evaluates the variability between individual trajectories (Kristjansson, et al., 2007; Raudenbush, 2001; Willett & Sayer, 1994), is expressed as:

$$ß_{oi} = y_{oo} + u_{oi}$$

$$ß_{ti} = y_{10} + u_{1i}$$

In the level 2 equations, $ß_{oi}$ and $ß_{ti}$ act as dependent variables (Llabre, et al., 2004). The grand mean of all the intercepts and slopes correspond to y_{oo} and y_{10}, respectively (Collins, 2006; Llabre, et al., 2004; Willett & Sayer, 1994). These grand means, which represent the average trajectories, are referred to as fixed parameters (Llabre, et al., 2004; MacCallum, et al., 1997). The overall means, variances, and covariances of the intercept and slope are calculated from all the repeated observations. The inter-individual variability, deviation from the grand mean, of the intercept and slope are expressed as u_{oi} and u_{1i}, respectively (Collins, 2006; Llabre, et al., 2004; MacCallum, et al., 1997; Stull, 2008). Although not observed in the aforementioned equations, the covariance is an additional important aspect of growth curve models. The covariance examines the relationship or association between the intercept and slope (S. C. Duncan & Duncan, 1994; Stull, 2008).

A significant variance could be attributed to inter-individual heterogeneity in the intercept and/or slope of a latent growth curve model (Willett & Sayer, 1994, 1996). For example, it is not uncommon for individuals within a sample to report different starting points. Furthermore, it is unlikely that change within a specific domain occurs at an equal rate among individuals. When significant variance is observed in the latent variables, time-invariant and time-varying covariates can be incorporated into a growth curve model to account for such variability (Llabre, et al., 2004; MacCallum, et al., 1997; Stull, 2008; Willett & Sayer, 1994). To account for variability in the latent variables, covariates are incorporated into the following level 2 equations (Bollen & Curran, 2006; MacCallum, et al., 1997; Preacher, Wichman, MacCallum, & Briggs, 2008; Willett & Sayer, 1994):

$$ß_{oi} = y_{oo} + y_{01}h_i + u_{oi}$$

$$ß_{ti} = y_{10} + y_{11}h_i + u_{1i}$$

In these level 2 equations, y_{oo} and y_{10} represent the mean intercept and slope, respectively, when income, for example is equal to zero. Both y_{01} and y_{11} indicate the effect of income on each latent parameter (MacCallum, et al., 1997; Preacher, et al., 2008).

As mentioned in the aforementioned paragraphs, latent growth curve models are more advantageous over traditional statistical methods. Latent growth curve modelling is an appropriate choice for evaluating the interrelationship of change between multiple outcomes as well as modelling the potential effects of mediating variables across multiple time periods (MacCallum, et al., 1997; Willett & Sayer, 1994). Researchers may want to consider the use of latent growth curve models in evaluating change among health behaviours (Curran, et al., 1996).

3.8 Statistical Analysis of the Current Study:

For the purpose of this analysis, Canadians less than 12 years of age at cycle 1 were excluded. Justification for the exclusion of such individuals was based upon the fact that questions pertaining to alcohol consumption, leisure-time physical activity energy expenditure, and smoking were not asked among Canadians under the age of 12 years. It is expected that excluding these younger Canadians would not influence the findings of this analysis as individuals do not typically begin to participate in unhealthy behaviours

including smoking (Everett, et al., 1999; Hammond, 2005; Harrell, Bangdiwala, Deng, Webb, & Bradley, 1998) and alcohol consumption (Faden, 2006; Swahn, Bossarte, & Sullivent, 2008) until after the age of 12. Additional criteria for exclusion was based upon the number of valid responses that individuals provided for each health behaviour. A response was deemed valid if the individual provided an answer that did not include one of the following: "not applicable", "don't know", "refusal", or "not stated". Excluded from this analysis were individuals who were unable to offer a valid response for any of the three health behaviours at any of the seven assessment periods. As these individuals provide no information in the development of the growth curve model, these individuals would automatically be excluded from the analysis. On the other hand, individuals providing at least one valid response for any one of the three dependent variables during any of the first seven cycles were included in this analysis. Consequently, individuals may only contribute one data point for each growth curve model.

Univariate analyses were performed on each dependent and independent variable. As previously mentioned, dependent variables included alcohol consumption, leisure-time physical activity, and smoking, while independent variables consisted of gender (male and female), chronological age (in years), marital status (married/common-law, single, formerly married), education (less than secondary school, secondary school graduation, some post-secondary schooling, and post-secondary graduation), income adequacy (lowest income, lower middle income, middle income, upper middle income, highest income, and missing income), BMI, and the number of chronic conditions diagnosed by a health professional. At each of the seven assessment periods, the mean, median, and standard deviation was calculated for continuous variables. Continuous variables included each dependent variable, chronological age, BMI, mastery, and the number of chronic conditions diagnosed by a health professional. In addition to these descriptive statistics, the assumption of normality among the three continuous dependent variables was tested by examining their respective skewness and kurtosis. The assessment of skewness and kurtosis are essential in determining whether variables violate the assumption of non-normality (Olsson, Foss, Troye, & Howell, 2000). The assumption of normality for each dependent variable was further evaluated by the findings of a

Kolmogorov-Smirnov test. In the case of categorical independent variables, frequency distributions were calculated at each cycle of the NPHS.

A logistic regression model with odds ratios (ORs) and corresponding 99% confidence intervals (CIs) was employed to examine predictors of attrition. The outcome variable of this model, attrition at the final follow-up period, was comprised of two categories: i) non-participation [reference category], and ii) participation. Those individuals in the participation category provided valid responses for the variables of interest at the final follow-up period. These variables of interest included all three health behaviours as well as gender, chronological age of respondent, marital status, education, income adequacy, BMI, mastery, and the number of chronic conditions diagnosed by a health professional. The non-participation category included individuals who provided partial responses or were non-responsive for the aforementioned variables. The attrition model was adjusted for various baseline variables including gender (male [reference category], female), chronological age of respondent (in years), marital status (single [reference category], married or common-law, formerly married), education (less than secondary school [reference category], secondary school graduation, some post-secondary school, post-secondary graduation), income adequacy (lowest income [reference category], lower middle income, upper middle income, and highest income), BMI, mastery, physical activity (kcal/kg/day), smoking behaviour (number of cigarettes smoked daily), alcohol consumption (number of alcoholic drinks/day), as well as the number of chronic conditions diagnosed by a health professional.

To assess the proportion of individuals reporting unhealthy behaviours across the seven assessment periods, alcohol consumption, leisure-time physical activity energy expenditure, and smoking were transformed from continuous to binary variables based upon specific health recommendations. Although continuous variables are more sensitive to behavioural changes, health guidelines are currently represented as binary variables. Therefore, to assess what percentage of Canadians report unhealthy behaviours, binary variables were employed for this part of the analysis. Gender-specific criteria were utilized to define excessive alcohol consumption. Males and females who drank a minimum of 15 and 10 alcoholic drinks per week, respectively were identified as consuming unhealthy quantities of alcohol. These cut-offs have been employed by

Bondy et al. (1999) and Wilkins (2002). For leisure-time physical activity energy expenditure, individuals expending a minimum of 3.0 kcal/kg/day of energy during leisure-time activities met the recommended guidelines for physical activity (Haskell, Montoye, & Orenstein, 1985; Katzmarzyk & Tremblay, 2007). Consequently, those individuals who were unable to fulfill this criterion were considered physically inactive. Expending 3.0 kcal/kg/day of energy is equivalent to an hour of daily walking (T. A. Barnett, Gauvin, Craig, & Katzmarzyk, 2008). A similar cut-off has been used by others to define an active lifestyle (Da Costa, Lowensteyn, & Dritsa, 2003; W. K. deRuiter, et al., 2008; Gauthier, et al., 2012; Stephens, Craig, & Ferris, 1986) . Finally, individuals who currently smoked, either daily or occasionally failed to meet the health guidelines for smoking behaviour. Using the aforementioned health recommendations, these three health behaviours were used independently as well as in conjunction to assess the percentage of Canadians who participated in the following unhealthy behaviours: 1) excessive alcohol consumption, 2) leisure-time physical inactivity, 3) smoking, 4) excessive alcohol consumption and leisure-time physical inactivity, 5) leisure-time physical inactivity and smoking, 6) excessive alcohol consumption and smoking, as well as 7) excessive alcohol consumption, leisure-time physical inactivity, and smoking. The percentage of Canadians who met the recommended guidelines for all three health behaviours was also calculated.

The primary objective of this study was to evaluate the interrelationship of multiple health behaviours. Parallel process models appeared to be an appropriate statistical method for this analysis as the growth factors of multiple health behaviours could be evaluated simultaneously. In total, three parallel process models were evaluated as only one health behaviour was simultaneously modelled onto another health behaviour. These three models were: 1) alcohol consumption and leisure-time physical activity, 2) leisure-time physical activity and smoking, and 3) alcohol consumption and smoking.

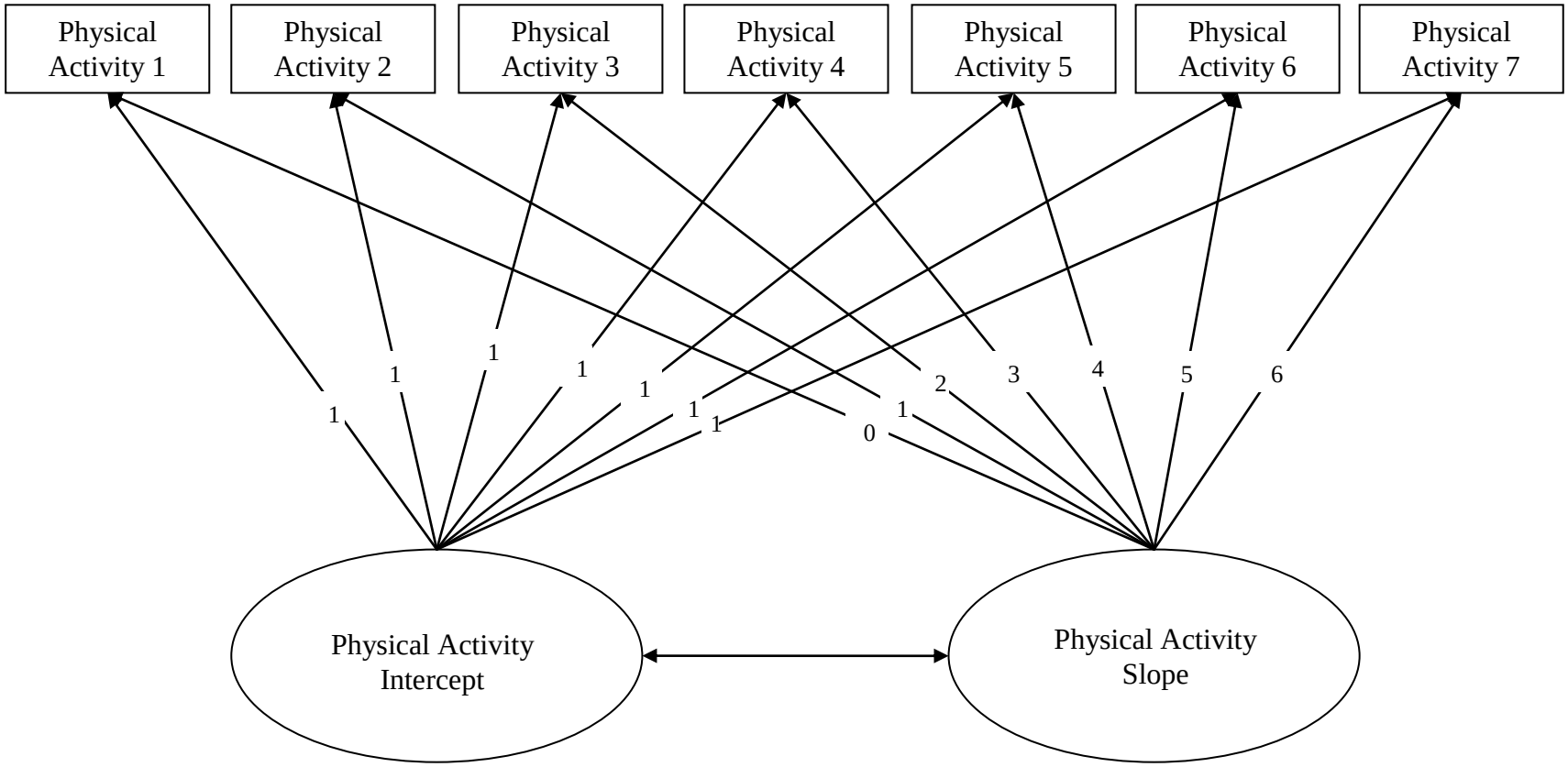
The development of each parallel process model involved a three step approach that is recommended by MacCallum et al. (1997) and employed by others (Curran, et al., 1996; Curran, et al., 1997; Stoolmiller, 1994). In the initial step, the existence of change as well as the longitudinal growth trajectory for each health behaviour was evaluated in a linear unconditional model. An unconditional model represents a model that does not include

covariates. Three linear unconditional models were developed by utilizing all seven repeated measures for alcohol consumption, leisure-time physical activity energy expenditure, and smoking. In each linear unconditional model, the repeated measures signified the dependent variables, while the latent intercept and slope represented the independent variables. A latent variable represents a variable that cannot be directly observed (Park & Schutz, 2005). As mentioned previously, the intercept indicates the initial status or starting point of a health behaviour, while the slope represents the rate of change across time for that particular lifestyle behaviour. In each of the three linear unconditional models, the factor loadings of the intercept were fixed at 1.0. Fixing the factor loadings of the intercept at 1.0 established the starting point of each trajectory at the first time period and allowed the intercept to stay constant and equally influence all seven repeated measures (Wu, West, & Taylor, 2009). The factor loadings associated with the slope indicate the time structure of the repeated measures (Willett & Sayer, 1994; Wu, et al., 2009). In a linear unconditional model, factor loadings of the slope were fixed at 0, 1.0, 2.0, 3.0, 4.0, 5.0, and 6.0 to correspond with all seven repeated measures. Fixing the first observation at 0 defines the intercept as the initial assessment period (T. E. Duncan & Duncan, 2004; Stull, 2008). The covariance and correlation between the intercept and slope were also evaluated for each of the three linear unconditional health behaviour models (S. C. Duncan & Duncan, 1994; Park & Schutz, 2005). Maximum likelihood estimation was employed for each growth curve model (L. K. Muthen & Muthen, 1998-2011). Unlike traditional statistical methods, the use of maximum likelihood estimation incorporates all available data and thus individuals are not excluded from the analysis for incomplete data (S. C. Duncan & Duncan, 1994; Francis, et al., 1991).

An example of a linear unconditional model is illustrated in Figure 1. In Figure 1, the solid lined boxes represent the repeated measurements of the dependent variable leisure-time physical activity energy expenditure for each of the seven cycles of the NPHS. The two ovals in Figure 1 represent the latent variables; the intercept and slope. The single headed arrows indicate a causal relationship between the latent variables and the repeated measures of leisure-time physical activity. The numbers assigned to each single headed arrow indicate the designated factor loadings for the intercept and slope. Both the

covariance and correlation between the latent variables are represented by the double-headed arrow which indicates a non-directional relationship between the intercept and slope.

Figure 1: Linear Unconditional Growth Curve Model: Physical Activity



Model fit, which assesses how well a particular model fits the sample data (Schermelleh-Engel, Moosbrugger, & Muller, 2003), is typically assessed by examining the chi-square goodness-of-fit statistic (X^2) as well as additional fit indices (Hu & Bentler, 1999; Wu, et al., 2009). A non-significant chi-square test statistic indicates that a model fits the data well (Bollen & Curran, 2006; Park & Schutz, 2005; Schermelleh-Engel, et al., 2003). However, the chi-square test statistic is often susceptible to bias, demonstrating a significant discrepancy between the hypothesized model and the distribution of the sample data when variables violate the assumption of multivariate normality or when large sample sizes are analyzed (Bollen & Curran, 2006; Park & Schutz, 2005; Schermelleh-Engel, et al., 2003; Stull, 2008; Wu, et al., 2009). This bias is attributed to an increase in statistical power which subsequently enhances the ability to identify the slightest discrepancy in the mean or covariance structure (Bollen & Curran, 2006). Due to the substantial sample size of the current analysis, a significant chi-square test statistic was expected. Therefore, the chi-square goodness-of-fit statistic was supplemented with additional fit indices. The utilization of multiple fit indices should be a common practice for examining model fit (Hu & Bentler, 1999; Schermelleh-Engel, et al., 2003). The standardized root mean squared residual (SRMR) when used in combination with the root mean square error of approximation (RMSEA) results "in acceptable Type II error rates for simple and complex misspecified models" (Hu & Bentler, 1999, pg. 27). For this approach, well fitting models report SRMR and RMSEA values of less than 0.05 and 0.06, respectively (Hu & Bentler, 1999). MacCallum and Austin (2000) have also recommended the incorporation of RMSEA in assessing model fit. Another approach in assessing model fit would be the inclusion of the comparative fit index (CFI) in conjunction with the SRMR at cut-offs of 0.96 and 0.09, respectively (Hu & Bentler, 1999). The use of the CFI and SRMR indices produces "the least sum of Type I and Type II error rates" (Hu & Bentler, 1999, pg. 27). Thus, in addition to the chi-square test statistic, three fit indices, CFI, SRMR, and RMSEA, were used to evaluate model fit in this analysis.

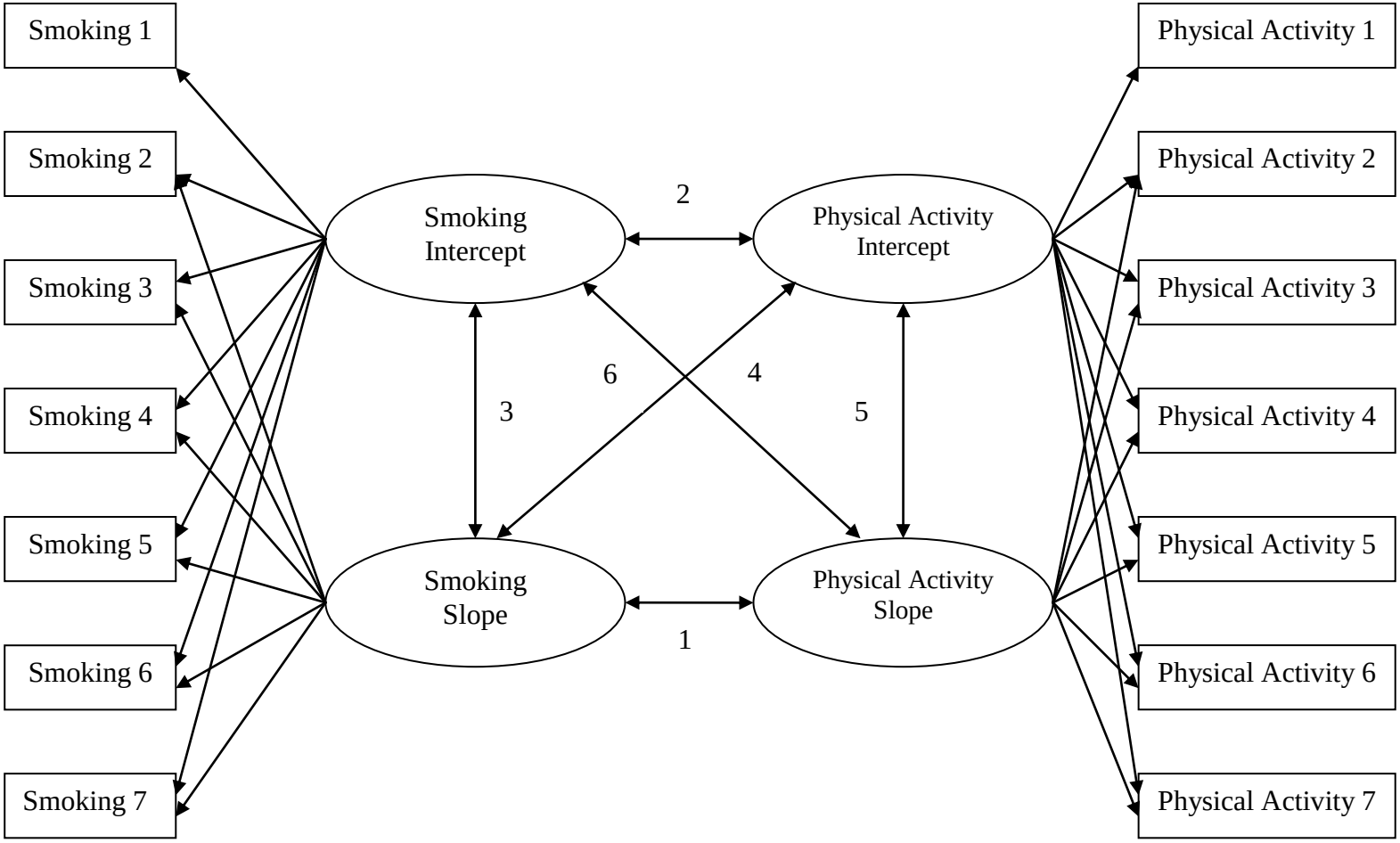
If the presence of change for any health behaviour was established in the form of a significant linear slope ($p<0.01$), a quadratic unconditional model was tested to determine if the longitudinal trajectory was nonlinear. A quadratic unconditional model is similar to

a linear unconditional model with the exception of an additional latent variable, a quadratic slope, which depicts the curvilinear trajectory (L. K. Muthen & Muthen, 1998-2011; Park & Schutz, 2005; Stull, 2008; Willett & Sayer, 1994). Compared to the linear factor loadings, factor loadings for a quadratic slope are squared (L. K. Muthen & Muthen, 1998-2011); 0, 1, 4, 9, 16, 25, and 36. A chi-square difference test was employed to determine whether the inclusion of a quadratic growth factor would improve the fit of the model (Llabre, et al., 2004; Willett & Sayer, 1994).

Once the shape or trajectory of each health behaviour was established, the second step in the development of a parallel process model involved the simultaneous evaluation of multiple health behaviours. By modelling health behaviours simultaneously, the covariances between the four latent variables could be evaluated. It is these covariances that denote whether health behaviours were interrelated. In total, six covariances were examined in each parallel process model. Figure 2 illustrates a parallel process model for leisure-time physical activity energy expenditure and smoking. The slope-slope covariance was the primary focus of each parallel process model as this covariance revealed whether changes in one health behaviour was associated with changes in the other health behaviour. In Figure 2, the slope-slope covariance is indicated by the number 1. In addition to the slope-slope covariance, each parallel process model also incorporated five additional covariances. Outlined in Figure 2, these additional covariances included the following: 2) the intercept of leisure-time physical activity energy expenditure and the intercept of smoking, 3) the intercept of smoking and the slope of smoking, 4) the intercept of leisure-time physical activity energy expenditure and the slope of smoking, 5) the intercept of leisure-time physical activity energy expenditure and the slope of leisure-time physical activity energy expenditure, and 6) the intercept of smoking and the slope of leisure-time physical activity energy expenditure. Although covariance estimates indicate the direction and significance of the association between an independent and dependent variable, the strength of this relationship is difficult to interpret (H. Frank & Althoen, 1994; Kitchens, 1998). In an attempt to determine the strength of each covariance, correlations were also calculated. Thus, to correspond with each covariance, six correlations were included in each parallel process

model. Similar to the unconditional models, model fit was evaluated by the following fit indices; chi-square goodness-of-fit statistic, CFI, SRMR and RMSEA.

Figure 2: Parallel Process Growth Curve Model: Leisure-Time Physical Activity and Smoking



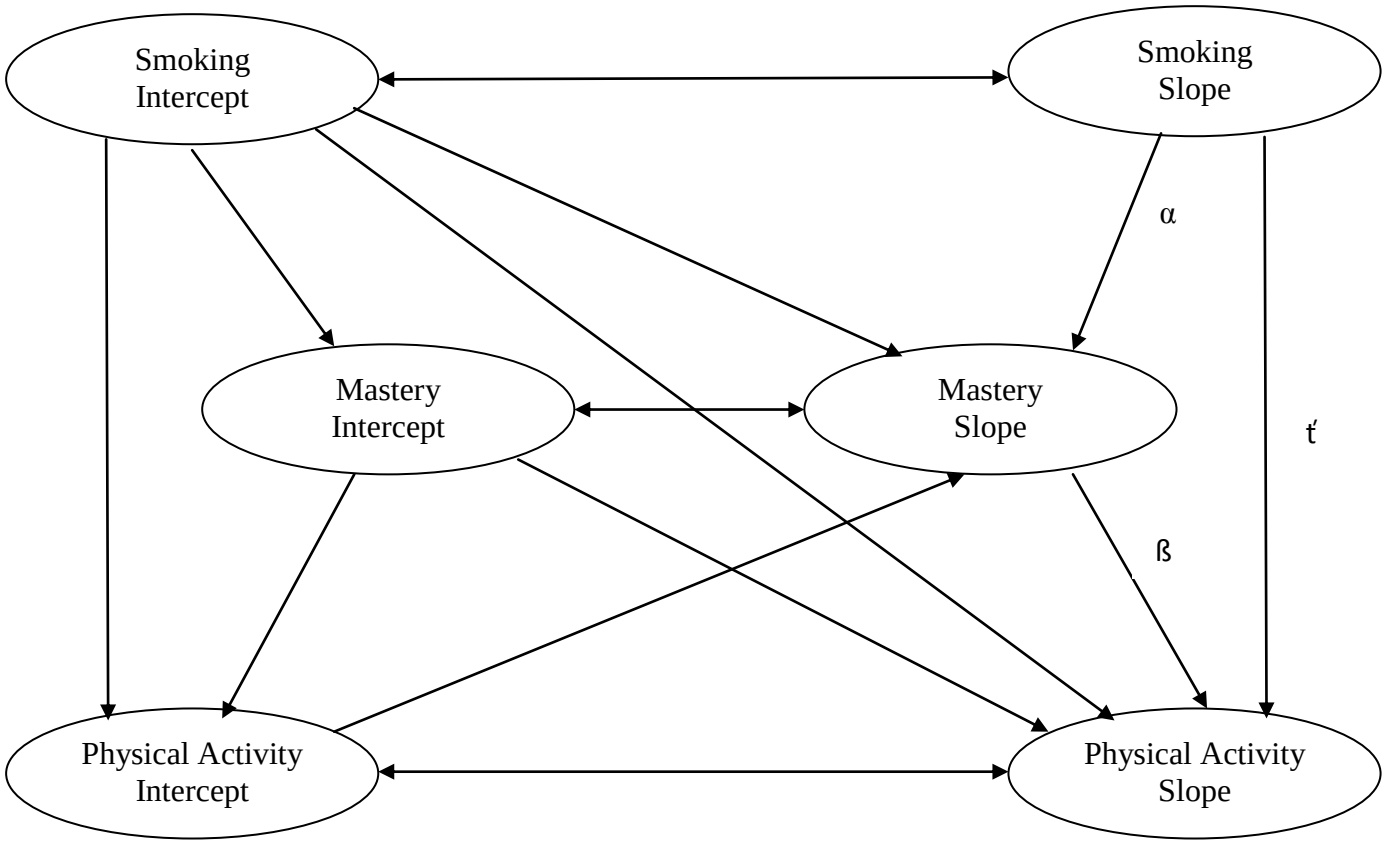
A significant variance in either the intercept and/or slope is an indication of individual differences in health behaviours and suggests that the addition of covariates may help in explaining such heterogeneity (Llabre, et al., 2004; Willett & Sayer, 1994). Latent growth curve models can include both time-invariant and time-varying covariates to explain variation in each of the latent variables. Consequently, in the final step, demographic characteristics as well as BMI were incorporated into each parallel process model. In total, six covariates were evaluated. For the purpose of interpretability, five of six covariates were binary variables. Binary covariates were created by collapsing categories of the previously mentioned independent variables. Time-invariant covariates were represented by gender (male [reference category] and female) and chronological age (in years). Time-varying covariates included marital status (married or co-habiting [reference category] and single or formerly married), education (high school graduation or less [reference category] and some post-secondary education or more), income adequacy (low income [reference category] and high income), and BMI (underweight/normal weight [reference category] and overweight/obese). The category underweight/normal weight was defined as a BMI of $\leq$24.9 kg/m^2. Body mass index categories were based upon the criteria put forth in the Canadian Guidelines for Body Weight Classification in Adults (Health Canada, 2005). For simpler interpretation of the findings, each of the six covariates were entered separately into each of the three parallel process models; alcohol consumption and leisure-time physical activity, leisure-time physical activity and smoking, and alcohol consumption and smoking. In other words, three parallel process models were created for gender, age, marital status, education, income adequacy, and BMI, respectively. Initially, when adjusting each parallel process model for the aforementioned independent variables, the statistical analysis program executed a listwise deletion in which individuals with missing values on any covariate during any cycle were excluded from the analysis. In an attempt to prevent this listwise deletion from occurring, the current analysis elected to use multiple imputation to fill in missing information with plausible responses for each of the six covariates. Five simulated versions of data were created with the average estimate of each parameter, covariance, and correlation being reported. Typically, only three to five simulated versions of data are necessary to acquire valid findings (Schafer & Olsen, 1998).

The secondary objective of the current study was to examine whether mastery acts as a mediating cognitive mechanism that facilitates successful changes within multiple health behaviours. In a causal association, an independent variable can influence a dependent variable either through a direct pathway or an indirect pathway which involves the inclusion of a mediating variable (MacKinnon, Fairchild, & Fritz, 2007). A variable acts as a mediator if it partially or completely accounts for a causal association between an independent and dependent variable (Baron & Kenny, 1986; MacKinnon, et al., 2007). The mediation of a variable is determined by evaluating whether the latent slope of the independent variable significantly influences the latent slope of the mediating variable and consequently significantly affects the growth of the dependent variable (MacKinnon, 2008; MacKinnon, et al., 2007). Parallel process models can be utilized to test for the potential mediating effects of variables such as mastery (Cheong, Mackinnon, & Khoo, 2003; MacKinnon, 2008). Figure 3 depicts a parallel process growth curve mediation model in which mastery mediates the interrelationship of the independent variable represented by smoking and the dependent variable denoted by leisure-time physical activity energy expenditure. To simplify Figure 3, the repeated measures of smoking, mastery, and leisure-time physical activity energy expenditure were not shown. In Figure 3, the indirect effect (αß) was the product of the coefficients between the slopes of the independent and mediating variables (α) and the slopes of the mediating and dependent variables (ß) (MacKinnon, et al., 2007; Rucker, Preacher, Tormala, & Petty, 2011). This approach to testing mediation is recommended (Cheung & Lau, 2008). A significant indirect effect is an indication that mastery mediates the interrelationship between health behaviours (Cheung & Lau, 2008). The direct effect, represented by ť, is the relationship between the slopes of independent and dependent variables after accounting for the slope of the mediating variable (Rucker, et al., 2011).

The assessment of a mediating variable is very similar to the evaluation of the interrelationship of health behaviours. Initially, the trajectory of each health behaviour as well as mastery was modelled independently across time (Cheong, et al., 2003; MacKinnon, 2008). After which, each longitudinal health behaviour was modelled simultaneously with mastery (Cheong, et al., 2003; MacKinnon, 2008). Once again, model fit was assessed by the chi-square goodness-of-fit statistic, CFI, SRMR and

RMSEA. The direct and indirect effects were calculated for each parallel process mediation model. In total, six mediation models were evaluated: 1) alcohol consumption and physical activity, 2) physical activity and alcohol consumption, 3) physical activity and smoking, 4) smoking and physical activity, 5) alcohol consumption and smoking, and 6) smoking and alcohol consumption.

Figure 3: Mediation Growth Curve Model: Smoking, Mastery, and Physical Activity



Univariate analyses, the prevalence rates of single and multiple behaviours, and the logistic regression modelling were conducted using Statistical Package for the Social Sciences (SPSS Software, 2009). Latent growth curve models were developed with MPLUS version 5.2 (L. K. Muthen & Muthen, 2010). Longitudinal sampling weights developed by Statistics Canada were utilized for this statistical analysis. Omitting such weights can result in selection bias (Asparouhov, 2005) as estimates would not be reflective of the Canadian general population at 1994/1995 (Statistics Canada, 2008). Bias-corrected 99% confidence intervals were requested for each latent growth curve model as such intervals "take non-normality of the parameter estimate distribution into account" (L. K. Muthen & Muthen, 1998-2011, pg. 613). Furthermore, when testing mediation, bias-corrected confidence intervals should be calculated and reported as the indirect effect is typically not normally distributed (Cheung & Lau, 2008). Due to the substantial sample size of the NPHS, the level of significance for this research study was established at 0.01. This study received ethics approval from the SSHRC of Canada as well as the University of Toronto.

Chapter 4
Results

4.1 Inclusion and Exclusion Criteria:

Initially, 17,276 Canadians were recruited to participate in the longitudinal NPHS. However, for the purpose of this study, 2,022 Canadians were excluded from the analysis as they represented individuals who were under the age of 12 at cycle 1. An additional 87 Canadians were excluded as they were unable or unwilling to provide at least one valid response for any one of the three health behaviours of interest. The remaining individuals within the NPHS database were 12 years of age or older at baseline and provided at least one valid response for either alcohol consumption, leisure-time physical activity energy expenditure, or smoking behaviour. Consequently, it was these 15,167 Canadians that were the focus of this longitudinal analysis.

4.2 Attrition:

In an attempt to differentiate between individuals who had completed the NPHS at cycle 7 and those who declined or were incapable of fully completing the longitudinal survey, demographic, cognitive-behavioural, behavioural and physical health characteristics were evaluated in a logistic regression. Odds ratios and corresponding 99% confidence intervals are reported in Table 12 for each characteristic of interest. The likelihood that individuals participated in the seventh cycle of the NPHS was increased among Canadians who were younger, married or formerly married, better educated, with a higher income adequacy, and a greater BMI score at the first cycle. Those individuals with higher levels of self perceived mastery at baseline were also more likely to complete the NPHS at the seventh cycle. In regards to behavioural characteristics, leisure-time physical activity energy expenditure was unrelated to participating in the NPHS at the final follow-up. However, that was not the case for smoking and alcohol consumption as these two behaviours demonstrated significant associations with the attrition variable. Smoking was associated with participation such that with every additional cigarette smoked per day, the likelihood of participation in the seventh cycle decreased by 1%. Contrary to smoking, greater quantities of alcohol consumption was associated with an

increased probability of participating in the seventh cycle of the NPHS. Finally, the odds of remaining in the NPHS at the seventh cycle were reduced by 7% for every additional physical health condition that an individual reported. The implications of these attrition results could be substantial. As attrition appears to influence specific individuals, the generalizability of these findings in the later cycles is debatable. In addition, the covariances and correlations discussed in the following paragraphs could be subjected to bias as Canadians who were less likely to adopt smoking cessation or consume higher quantities of alcohol demonstrated a greater likelihood of withdrawing from this analysis during the seventh cycle.

Table 12: Baseline Characteristics that Predict Participation at the Seventh Cycle (n = 12,349)

	Odds Ratio	99% CI
Demographic Characteristics		
Gender:		
Male	1.00	
Female	1.05	0.92 – 1.20
Chronological Age (Years)	0.97 *	0.96 – 0.97
Marital Status:		
Single	1.00	
Married or Common-Law	1.57 *	1.31 – 1.88
Formerly Married	1.71 *	1.35 – 2.17
Education:		
Less than Secondary School	1.00	
Secondary School Graduation	1.20	0.96 – 1.51
Some Post-Secondary School	1.46 *	1.21 – 1.76
Post-Secondary School Graduation	1.73 *	1.43 – 2.09
Income Adequacy:		
Lowest Income	1.00	
Lower Middle Income	1.49 *	1.21 – 1.85
Upper Middle Income	1.91 *	1.57 – 2.33
Highest Income	2.76 *	2.11 – 3.60
Body Mass Index (Kg/M^2)	1.02 *	1.00 – 1.03
Cognitive-Behavioural Characteristics		
Mastery	1.02 *	1.00 – 1.03
Behavioural Characteristics		
Alcohol Consumption (Drinks/Day)	1.08 *	1.01 – 1.16
Leisure-Time Physical Activity (Kg/Kcal/Day)	0.99	0.96 – 1.02
Smoking (Cigarettes/Day)	0.99 *	0.98 – 1.00
Physical Health Characteristics		
Number of Chronic Conditions	0.93 *	0.88 – 0.98

* Significant at $p \leq 0.01$.

4.3 Sample Characteristics:

Weighted demographic, cognitive-behavioural as well as behavioural characteristics for this Canadian sample are illustrated in Table 13. In 1994/1995, a slight majority of this sample was female. On average, the age of this sample increased from 41 years at the first cycle to 51 years at the seventh cycle. The majority of Canadians, 58.9%, were married at the first assessment period. Single individuals represented 29.0% while 12.2% of the sample was comprised of formerly married individuals; those Canadians who were widowed, separated or divorced. By 2006/2007, the proportion of married and formerly married individuals had increased to 66.5 and 18.0%, respectively, whereas the percentage of single individuals had decreased to 15.4%. Individuals appeared to have attained higher levels of education over the 12 year period. Those who had acquired some post-secondary schooling increased by 2.5%, while the percentage of individuals who had graduated from post-secondary school increased from 28.7 to 44.7%. Income adequacy seems to improve between 1994/1995 to 2006/2007 as the highest income category increased from 15.1% in the first cycle to 25.6% in the seventh cycle. With the exception of the missing category, the remaining income adequacy groupings decreased substantially over the 12 year time period. Attrition could have been responsible for this trend in income adequacy as the proportion of Canadians within the missing category increased over time. Over 12 years, the average BMI score increased from 24.8±4.6 kg/m^2 to 26.6±5.0 kg/m^2. Consequently, the proportion of Canadians who were considered overweight or obese ($\geq$25 kg/m^2) increased from 44.0 to 60.3%. Mastery, a cognitive-behavioural variable, reported mean scores ranging between 19.6±4.3 to 19.9±3.8. Daily alcohol consumption remained fairly stable during the first three cycles before increasing slightly at the fourth cycle. By the seventh cycle, an additional rise in the daily consumption of alcohol had occurred. Daily leisure-time physical activity energy expenditure exhibited an overall increasing trend. Deviations from this increasing trend were observed at cycle 4 and cycle 6. Among each of three health behaviours evaluated, smoking behaviour, measured by the number of cigarettes smoked per day, was the only behaviour to decrease during the longitudinal cycles. Smoking behaviour decreased from a peak of 4.7±9.5 cigarettes per day at the first cycle to a low of 2.7±6.7 cigarettes per day by the seventh cycle.

Table 13: Weighted Demographic, Cognitive-Behavioural, and Behavioural Characteristics

	Cycle 1 n = 15,167	Cycle 2 n = 13,953	Cycle 3 n = 12,900	Cycle 4 n = 11,938	Cycle 5 n = 10,976	Cycle 6 n =10,112	Cycle 7 n = 9,728
Gender (%):							
Male	49.0	49.1	49.0	48.2	47.9	47.6	48.0
Female	51.0	50.9	51.0	51.8	52.1	52.4	52.0
Age (Mean±SD):	40.9±18.5	42.7±18.3	44.4±18.1	46.1±17.8	47.6±17.5	49.4±17.0	50.9±16.6
Age (Median):	39.0	40.0	42.0	44.0	46.0	48.0	49.0
Marital Status (%):							
Married or Common-Law	58.9	58.9	59.8	61.1	62.9	65.1	66.5
Single	29.0	27.7	25.5	23.1	20.4	17.7	15.4
Formerly Married	12.2	13.4	14.8	15.7	16.7	17.2	18.0
Education (%):							
Less Than Secondary School	33.4	29.3	25.0	20.8	18.5	17.6	16.6
Secondary School Grad.	14.8	14.9	15.0	14.6	14.1	13.4	13.1
Some Post-Secondary School	23.1	25.6	27.4	28.4	27.5	26.1	25.6
Post-Secondary School Grad.	28.7	30.1	32.7	36.2	39.9	42.9	44.7
Income Adequacy (%):							
Lowest Income	17.0	13.0	10.0	7.5	5.9	4.4	3.1
Lower Middle Income	28.7	25.9	20.6	15.3	12.9	10.7	8.4
Upper Middle Income	34.2	33.0	29.6	26.8	23.5	20.7	18.3
Highest Income	15.1	12.9	18.6	20.7	22.6	24.0	25.6
Missing Income	5.0	15.2	21.1	29.7	35.2	40.1	44.6

Table 13: Weighted Demographic, Cognitive-Behavioural, and Behavioural Characteristics Continued

	Cycle 1 n = 15,167	Cycle 2 n = 13,953	Cycle 3 n = 12,900	Cycle 4 n = 11,938	Cycle 5 n = 10,976	Cycle 6 n =10,112	Cycle 7 n = 9,728
Body Mass Index (Kg/M^2) (Mean±SD):	24.8±4.6	25.0±4.5	25.4±4.5	25.8±4.7	26.1±4.9	26.3±4.8	26.6±5.0
Body Mass Index (Kg/M^2) (Median):	24.2	24.5	24.9	25.2	25.6	25.7	25.9
Body mass index (%):							
Under or Normal Weight	56.0	53.6	50.6	46.7	44.0	42.4	39.7
Overweight or Obese	44.0	46.4	49.4	53.3	56.0	57.6	60.3
Mastery (Mean±SD):	19.6±4.3	-	-	19.9±3.8	19.6±3.9	19.7±4.0	19.8±4.0
Mastery (Median):	20.0	-	-	21.0	20.0	20.0	21.0
Alcohol Consumption (Drinks/Day) (Mean±SD):	0.4±0.9	0.4±0.9	0.4±0.9	0.5±0.9	0.5±1.0	0.5±1.0	0.6±1.1
Alcohol Consumption (Drinks/Day) (Median):	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leisure-Time Physical Activity (Kcal/Kg/Day) (Mean±SD):	1.8±2.1	1.8±2.2	1.9±2.1	1.7±1.8	2.0±1.9	1.9±1.9	2.1±2.0
Leisure-Time Physical Activity (Kcal/Kg/Day) (Median):	1.1	1.2	1.3	1.2	1.5	1.4	1.6
Smoking (Cigarettes/Day) (Mean±SD):	4.7±9.5	4.5±8.9	4.2±8.3	3.8±7.8	3.1±7.1	2.9±6.9	2.7±6.7
Smoking (Cigarettes/Day) (Median):	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.4 Prevalence of Single and Multiple Health Behaviours:

Table 14 examines the prevalence of unhealthy behaviours at each cycle of data collection. The calculated prevalence rates indicate the percentage of individuals who participated in a particular unhealthy behaviour regardless of whether any additional behaviours may or may not have been present. The proportion of Canadians who were physically inactive, < 3.0 kcal/kg/day, significantly decreased from 80.4% in 1994/1995 to 73.5% in 2006/2007. Similar to leisure-time physical inactivity, smoking behaviour also demonstrated a favourable trend between 1994/1995 and 2006/2007. During the first four cycles of data collection, the percentage of daily and occasional smokers in this Canadian sample decreased by only 2.5%. However, by the seventh cycle, smokers represented only 21.3% of the current sample; a difference of 8.0% from the initial data collection period. Excessive alcohol consumption was the only behaviour that did not exhibit an encouraging trend throughout the full duration of the NPHS. The proportion of individuals participating in excessive alcohol consumption, ≥ 15 and ≥ 10 drinks per week for males and females, respectively, increased from 5.7 to 7.9% by the fifth cycle. At the seventh assessment period, excessive alcohol consumption had increased to 9.4% within the current sample.

Table 14: Weighted Sample Size and Prevalence of Unhealthy Behaviours

	Cycle 1		Cycle 2		Cycle 3		Cycle 4		Cycle 5		Cycle 6		Cycle 7	
	n	%	n	%	n	%	n	%	n	%	N	%	n	%
Excessive Alcohol Consumption	834	5.7	796	5.8	779	6.2	678	7.0	704	7.9	593	7.2	711	9.4 *
Leisure-Time Physical Inactivity	11,108	80.4	10,789	79.8	9,745	78.4	9,274	81.5	8,013	77.1	7,561	77.8	6,543	73.5 *
Smoking	4,301	29.3	3,993	29.0	3,525	27.7	3,169	26.8	2,547	23.6	2,193	21.9	2,009	21.3 *

*Difference between cycle 1 and cycle 7 was significant at $p \leq 0.01$.

The prevalence rates of single as well as multiple unhealthy behaviours at each data collection cycle are illustrated in Table 15. In 1994/1995, 13.7% of the Canadian sample had not participated in any unhealthy behaviour including excessive alcohol consumption, physical inactivity, and daily or occasional smoking behaviour. Over the remaining six cycles, the percentage of individuals possessing no unhealthy behaviours increased. This rise in prevalence rates appeared to be most evident between cycles 4 and 5. By the seventh cycle, nearly 20% of Canadians practiced all three healthy lifestyle behaviours; $\leq$ 14 and $\leq$ 9 alcoholic beverages per week for males and females, respectively, leisure-time physical activity of $\geq$ 3.0 kcal/kg/day, as well as non-smoking. Physical inactivity was the most prevalent independent unhealthy behaviour as the majority of Canadians, 52.0 to 55.8%, were physically inactive. Physical inactivity peaked at 55.8% during the sixth cycle before decreasing to 52.0% by the seventh cycle. Canadians who were exclusively smokers, either daily or occasional, ranged from 4.1 to 5.0%, while a small minority, 0.6 to 2.2%, of this Canadian sample only participated in excessive alcohol consumption.

Table 15: Weighted Prevalence of Single and Multiple Health Behaviours

	Cycle 1 n = 13,764	Cycle 2 n = 13,408	Cycle 3 n = 12,332	Cycle 4 n = 9,351	Cycle 5 n = 8,642	Cycle 6 n = 7,970	Cycle 7 n = 7,234
No Unhealthy Behaviours	13.7	14.0	15.0	13.3	17.5	16.5	19.7 *
Excessive Alcohol Consumption (Only)	0.6	0.8	1.0	1.0	1.3	1.4	2.2 *
Leisure-Time Physical Inactivity (Only)	54.0	54.3	54.0	54.8	52.9	55.8	52.0 *
Smoking (Only)	4.8	4.7	5.0	4.2	4.3	4.1	4.6 *
Excessive Alcohol Consumption & Leisure-Time Physical Inactivity	2.3	2.0	2.1	2.6	3.0	2.9	3.7 *
Leisure-Time Physical Inactivity & Smoking	21.5	21.1	19.7	20.6	17.3	16.1	14.2 *
Excessive Alcohol Consumption & Smoking	0.5	0.8	0.7	1.0	1.1	1.0	1.0 *
All Three Unhealthy Behaviours	2.6	2.3	2.5	2.7	2.7	2.1	2.6 *

*Difference between cycle 1 and cycle 7 was significant at $p \leq 0.01$.

The most common pairwise combination of unhealthy behaviours was physical inactivity and smoking (Table 15). In 1994/1995, nearly one quarter of this Canadian sample were physically inactive and smoking. With time, the proportion of physically inactive smokers had decreased to 14.2% in 2006/2007. Additional pairwise combinations of unhealthy behaviours were reported among a small minority of this Canadian sample. Physically inactive consumers of excessive alcohol ranged from 2.0 to 3.7%, while smokers who consumed high levels of alcoholic beverages represented 0.5 to 1.1% of this Canadian sample. Finally, approximately 2.5% of Canadians practiced all three unhealthy behaviours; excessive alcohol consumption, leisure-time physical inactivity, and smoking. Although a significant difference was observed between cycles 1 and 7, the prevalence rate of possessing all three unhealthy behaviours appeared to be fairly consistent over each of the seven cycles of data collection.

4.5 Unconditional Growth Curve Models of Health Behaviours:

Unconditional growth curve models were developed to track the longitudinal trajectories of alcohol consumption, leisure-time physical activity energy expenditure, and smoking. Univariate analyses revealed that each of the three health behaviours demonstrated substantial skewness and kurtosis (Table 16). A significant Kolmogorov-Smirnov test statistic ($p < 0.001$) provided further evidence that the assumption of normality was violated for all three health behaviours across all seven time periods. However, maximum likelihood estimation can provide accurate estimates notwithstanding violations of normality (Olsson, et al., 2000). In addition, the use of bootstrapping procedures that calculate confidence intervals has been suggested for analyzing non-normally distributed data (Bollen & Stine, 1990). To determine if contradictory findings would be obtained through the use of normally distributed data, this study incorporated a supplementary data analysis in which the observed repeated measures underwent a logarithmic transformation. Re-analyzing the unconditional, parallel process, and mediation models utilizing this logarithmically transformed data produced results that were comparable to the original findings.

Table 16: Weighted Measures of Normality

	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	Cycle 7
Alcohol Consumption:							
Skewness	4.3	4.3	3.8	3.5	3.9	4.2	3.2
Kurtosis	29.0	29.5	23.7	24.6	28.8	35.1	16.3
Leisure-Time Physical Activity:							
Skewness	3.0	2.7	2.5	2.6	2.0	2.0	1.9
Kurtosis	17.5	11.9	10.2	13.9	6.6	5.8	5.9
Smoking:							
Skewness	2.3	2.1	2.2	2.3	2.7	2.7	3.1
Kurtosis	6.6	4.5	5.0	5.5	7.8	8.4	12.2

4.5.1 Alcohol Consumption:

Table 17 presents the correlation coefficients for alcohol consumption across the seven cycles of data collection. Correlations between alcohol consumption measures were positive and typically demonstrated a decreasing trend across the seven cycles of data collection.

Table 17: Correlation Coefficients for Alcohol Consumption

	Cycle 1: Alcohol	Cycle 2: Alcohol	Cycle 3: Alcohol	Cycle 4: Alcohol	Cycle 5: Alcohol	Cycle 6: Alcohol	Cycle 7: Alcohol
Cycle 1: Alcohol	1.00						
Cycle 2: Alcohol	0.55	1.00					
Cycle 3: Alcohol	0.48	0.52	1.00				
Cycle 4: Alcohol	0.39	0.44	0.49	1.00			
Cycle 5: Alcohol	0.41	0.43	0.45	0.50	1.00		
Cycle 6: Alcohol	0.42	0.43	0.43	0.49	0.56	1.00	
Cycle 7: Alcohol	0.45	0.49	0.44	0.51	0.57	0.63	1.00

Initially, a linear model was estimated from the seven repeated measures of alcohol consumption. In Table 18, a significant chi-square statistic ($X^2[23] = 601.47$, $p < 0.01$) indicated poor fit for the linear model of alcohol consumption. However, a significant chi-square statistic was expected due to the substantial sample size employed for this analysis. The remaining fit indices in Table 18 demonstrated good fit for the linear model of alcohol consumption; CFI = 0.98, RMSEA = 0.04 (90% CI = 0.04 – 0.04), and SRMR = 0.03.

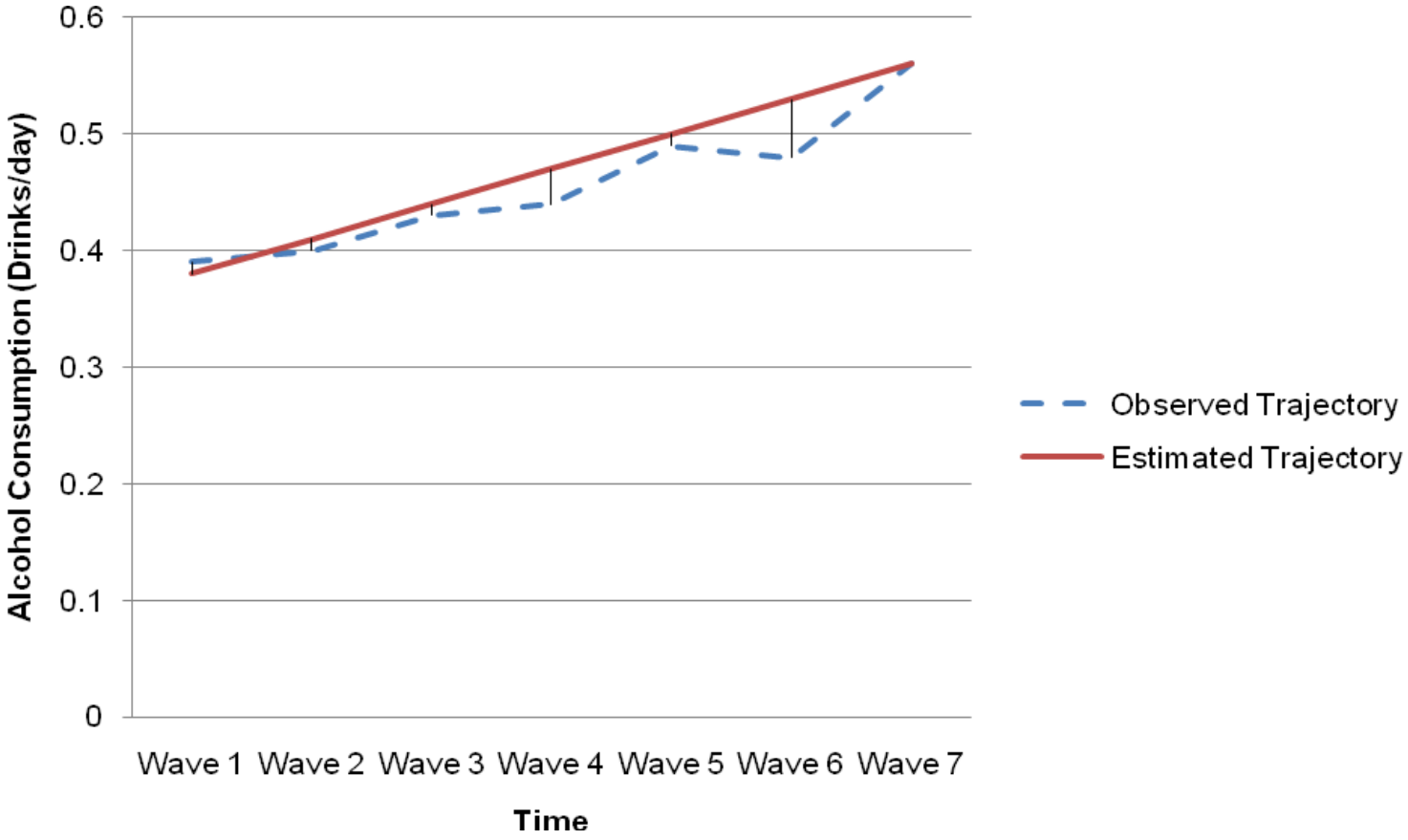
Table 18: Fit Indices for Unconditional and Parallel Process Models

	X^2 (df)	CFI	RMSEA	90% CI for RMSEA	SRMR
Alcohol Consumption	601.47 (23) *	0.98	0.04	0.04 – 0.04	0.03
Physical Activity	738.12 (23) *	0.97	0.05	0.04 - 0.05	0.03
Smoking	2590.28 (23) *	0.97	0.09	0.08 – 0.09	0.03
Alcohol Consumption & Physical Activity	1620.01 (91) *	0.97	0.03	0.03 – 0.04	0.03
Physical Activity & Smoking	3459.53 (91) *	0.97	0.05	0.05 – 0.05	0.02
Alcohol Consumption & Smoking	3655.01 (91) *	0.97	0.05	0.05 – 0.05	0.03

* Significant at $p \leq 0.01$.

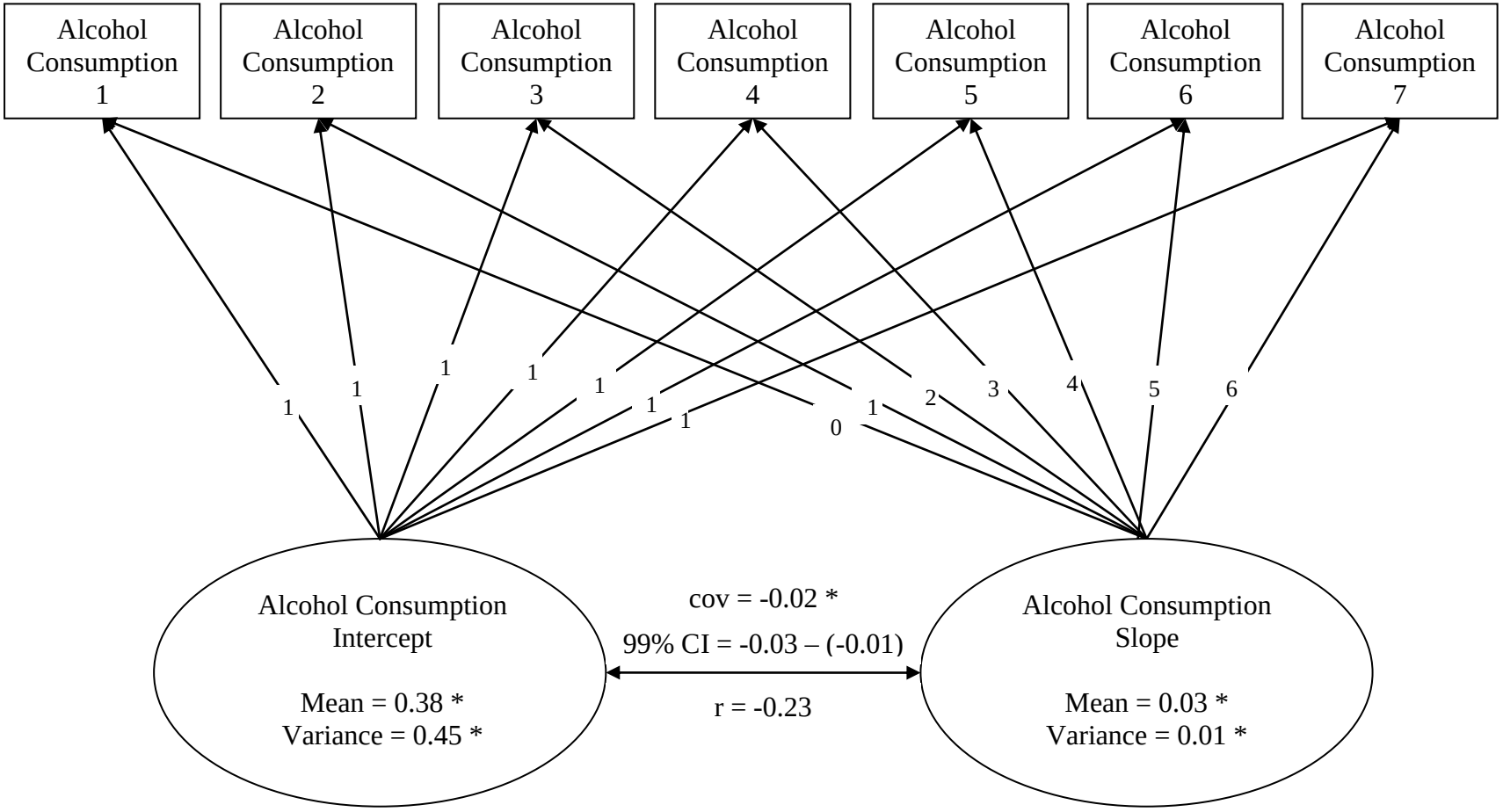
A quadratic model was also developed to determine whether alcohol consumption demonstrated a non-linear trajectory. A significant chi-square difference test, $X^2(4) = 326.37$, $p < 0.001$, confirmed that a quadratic model would provide superior fit in depicting the trajectory of alcohol consumption over a linear model. However, for reasons threefold, this analysis elected to employ a linear model to represent alcohol consumption. First, as depicted in Figure 4, the observed trajectory of alcohol consumption appears to increase in a linear fashion. Second, as indicated by the CFI, RMSEA, and SRMR, the linear model demonstrated good fit for the observed alcohol consumption data. Finally, compared to the linear analysis, the quadratic model includes an additional growth factor. The inclusion of this second growth factor increases the complexity of the model and consequently may produce findings that could become difficult to interpret.

Figure 4: Observed and Estimated Trajectories of Alcohol Consumption



The estimated means, variances, covariance and correlation for alcohol consumption are presented in Figure 5. In this sample of Canadians, the mean intercept of the linear model was 0.38 drinks per day (99% CI = 0.36 – 0.39, $p < 0.01$). The significant ($p < 0.01$) positive mean slope for alcohol consumption suggests that this sample of Canadians increased their alcohol consumption by 0.03 drinks per day (99% CI = 0.02 – 0.03) at each cycle of data collection. A significant variance in both the intercept and slope for alcohol consumption was indicative of substantial inter-individual variability that could be accounted for by the addition of time-invariant and/or time-varying covariates. The significant negative covariance (cov = -0.02, 99% CI = -0.03 – [-0.01], $p < 0.01$) between the intercept and slope of alcohol consumption revealed that Canadians who initially drank a greater number of alcohol beverages per day increased their consumption at a slower or flatter rate compared to their counterparts who initially drank lower quantities of alcohol. The estimated correlation between the latent variables of alcohol consumption ($r = -0.23$) indicated a weak relationship between the intercept and slope.

Figure 5: Linear Growth Curve Model of Alcohol Consumption (n = 15,153)



cov: Covariance; CI: Confidence Interval; r: Correlation.
99% Confidence intervals correspond to the covariance. Factor loadings were predetermined.
* Significant at $p \leq 0.01$.

4.5.2 Leisure-Time Physical Activity Energy Expenditure:

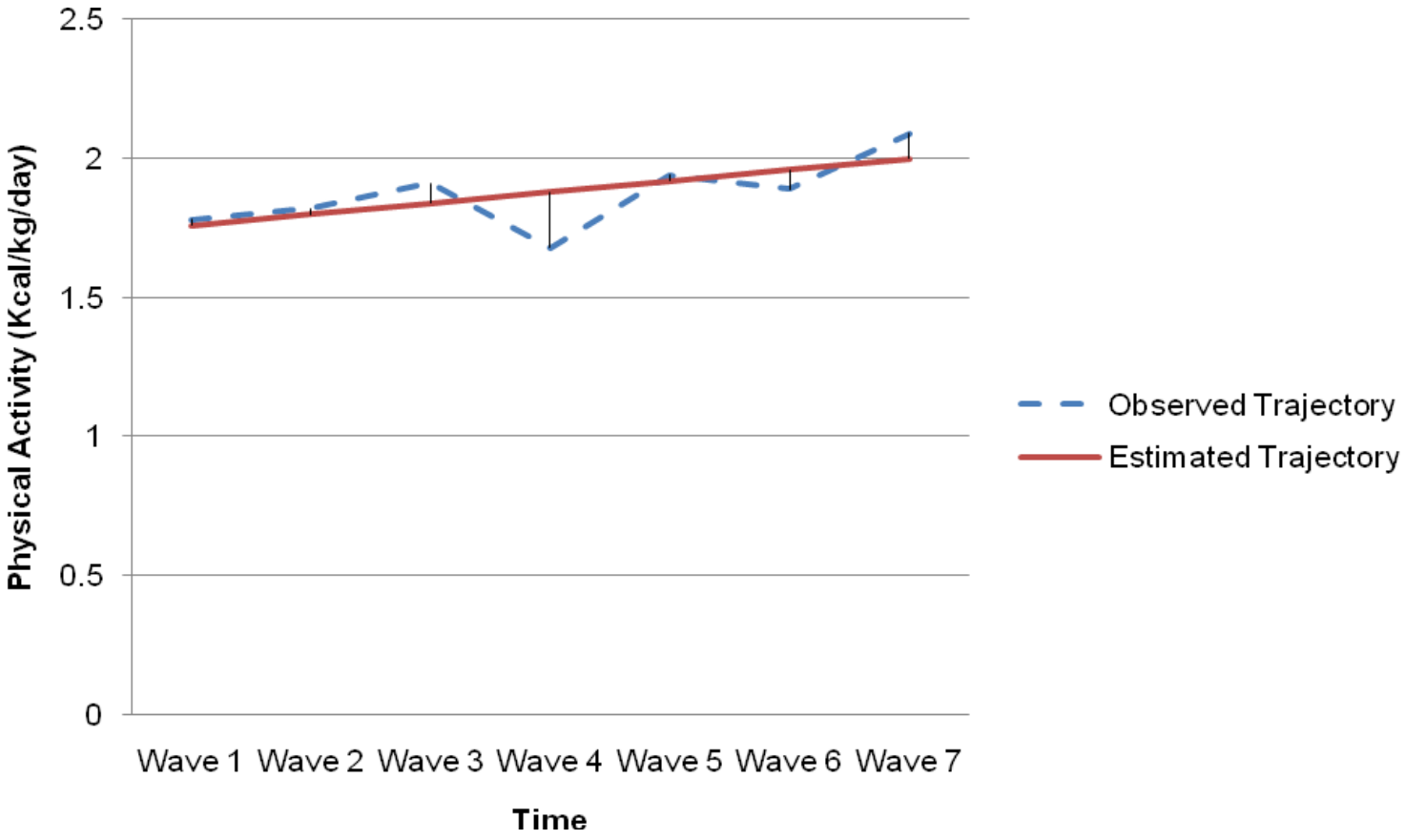
As presented in Table 19, correlations between the repeated measures for leisure-time physical activity energy expenditure were positive and decreased in strength with the passage of time.

Table 19: Correlation Coefficients for Leisure-Time Physical Activity

	Cycle 1: Physical Activity	Cycle 2: Physical Activity	Cycle 3: Physical Activity	Cycle 4: Physical Activity	Cycle 5: Physical Activity	Cycle 6: Physical Activity	Cycle 7: Physical Activity
Cycle 1: Physical Activity	1.00						
Cycle 2: Physical Activity	0.47	1.00					
Cycle 3: Physical Activity	0.44	0.48	1.00				
Cycle 4: Physical Activity	0.37	0.41	0.47	1.00			
Cycle 5: Physical Activity	0.35	0.39	0.43	0.49	1.00		
Cycle 6: Physical Activity	0.34	0.36	0.36	0.43	0.50	1.00	
Cycle 7: Physical Activity	0.31	0.35	0.38	0.41	0.45	0.52	1.00

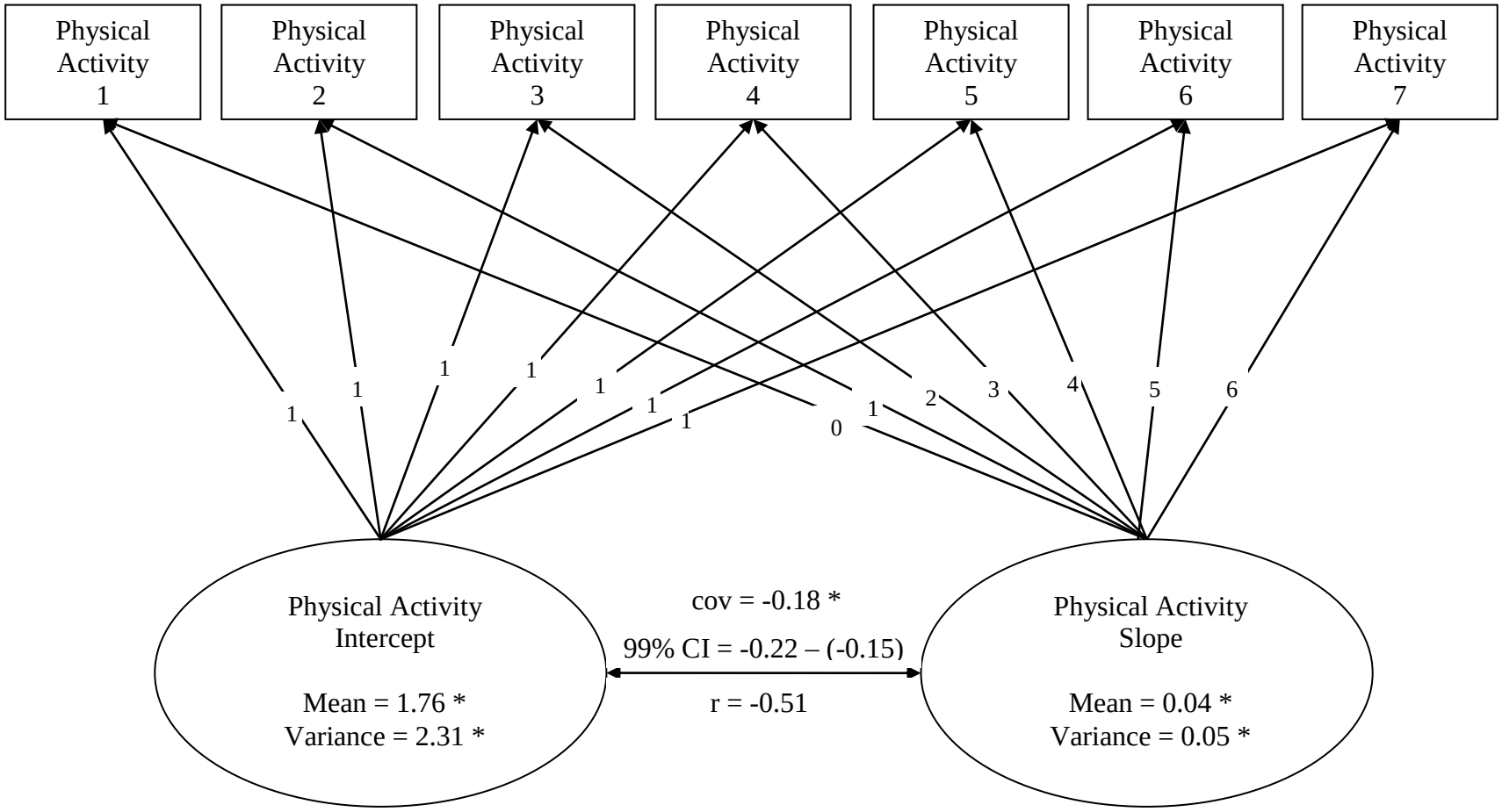
As illustrated in Table 18, although a significant chi-square statistic was observed, $X^2(23) = 738.12$, $p < 0.01$, the linear model for leisure-time physical activity revealed good fit; CFI = 0.97, RMSEA = 0.05 (90% CI = 0.04 – 0.05), and SRMR = 0.03. A significant chi-square difference test, $X^2(4) = 205.29$, $p < 0.01$, indicated that the addition of a quadratic factor would improve the fit of the leisure-time physical activity model. However, as with alcohol consumption, this analysis elected to utilize a linear model to represent leisure-time physical activity energy expenditure. The observed and estimated linear trajectories for leisure-time physical activity are represented in Figure 6.

Figure 6: Observed and Estimated Trajectories of Leisure-Time Physical Activity Energy Expenditure



As depicted in Figure 7, the mean intercept of leisure-time physical activity energy expenditure was 1.76 kcal/kg/day (99% CI = 1.71 – 1.80, $p < 0.01$). A significant positive trend ($p < 0.01$) in leisure-time physical activity was observed as Canadians increased their physical activity energy expenditure by 0.04 kcal/kg/day (99% CI = 0.03 – 0.05) biennially. Both the intercept and slope of physical activity demonstrated significant variances indicating inter-individual variability. The significant negative covariance (cov = -0.18, 99% CI = -0.22 – [-0.15], $p < 0.01$) between the intercept and slope of leisure-time physical activity energy expenditure suggests that those Canadians who initially reported high levels of leisure-time physical activity increased their energy expenditure at a slower rate. Conversely, Canadians participating in lower levels of leisure-time physical activity in 1994/1995, reported greater increases in physical activity over the subsequent cycles. The relationship between latent variables demonstrated moderate strength as indicated by the correlation ($r = -0.51$).

Figure 7: Linear Growth Curve Model of Leisure-Time Physical Activity Energy Expenditure (n = 15,056)



cov: Covariance; CI: Confidence Interval; r: Correlation.
99% Confidence intervals correspond to the covariance. Factor loadings were predetermined.
* Significant at $p \leq 0.01$.

4.5.3 Smoking:

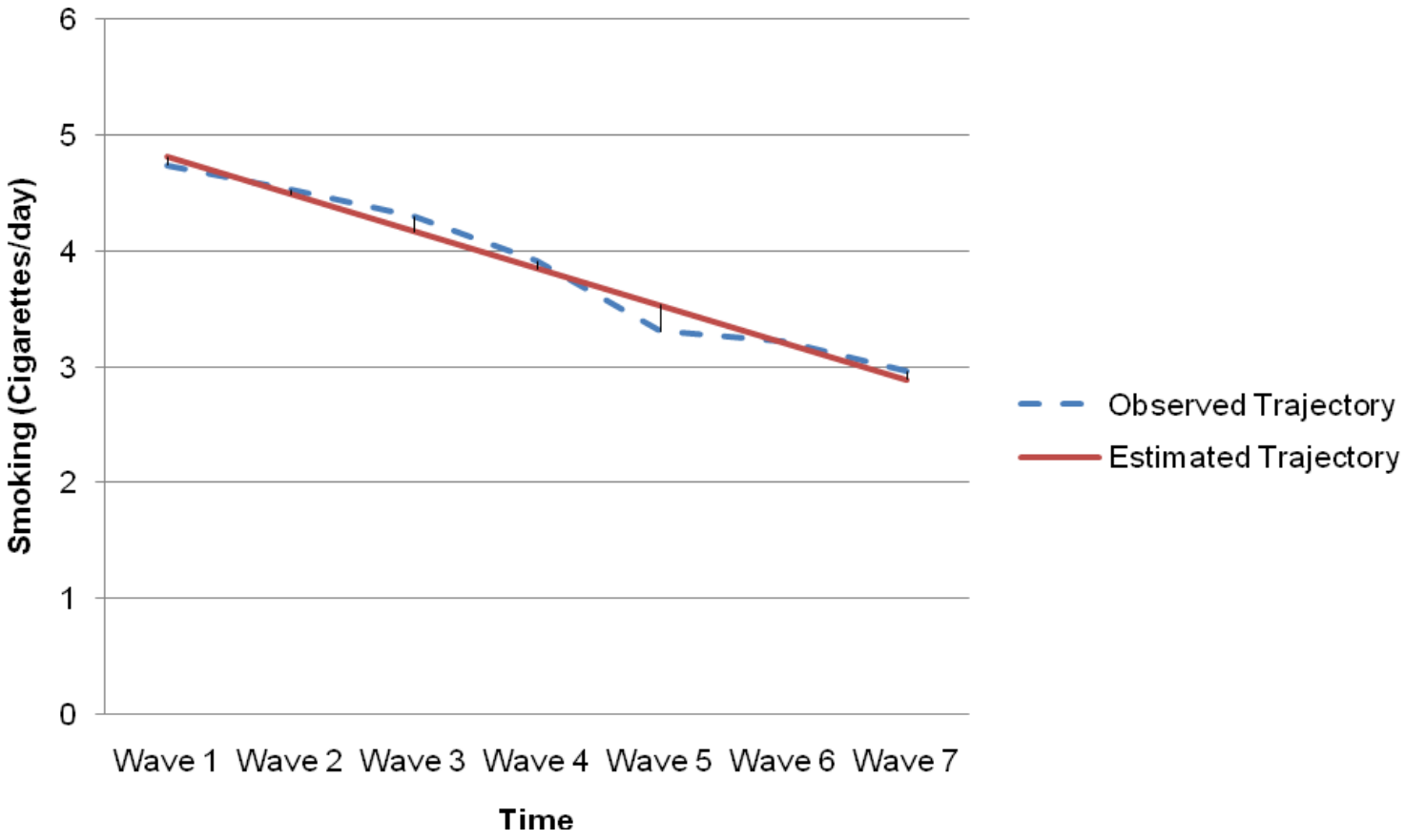
Similar to alcohol consumption and leisure-time physical activity, correlations for smoking were positive and decreased in strength over time (Table 20).

Table 20: Correlation Coefficients for Smoking

	Cycle 1: Smoking	Cycle 2: Smoking	Cycle 3: Smoking	Cycle 4: Smoking	Cycle 5: Smoking	Cycle 6: Smoking	Cycle 7: Smoking
Cycle 1: Smoking	1.00						
Cycle 2: Smoking	0.86	1.00					
Cycle 3: Smoking	0.79	0.83	1.00				
Cycle 4: Smoking	0.72	0.76	0.81	1.00			
Cycle 5: Smoking	0.66	0.70	0.74	0.82	1.00		
Cycle 6: Smoking	0.63	0.66	0.69	0.76	0.83	1.00	
Cycle 7: Smoking	0.62	0.65	0.67	0.74	0.80	0.86	1.00

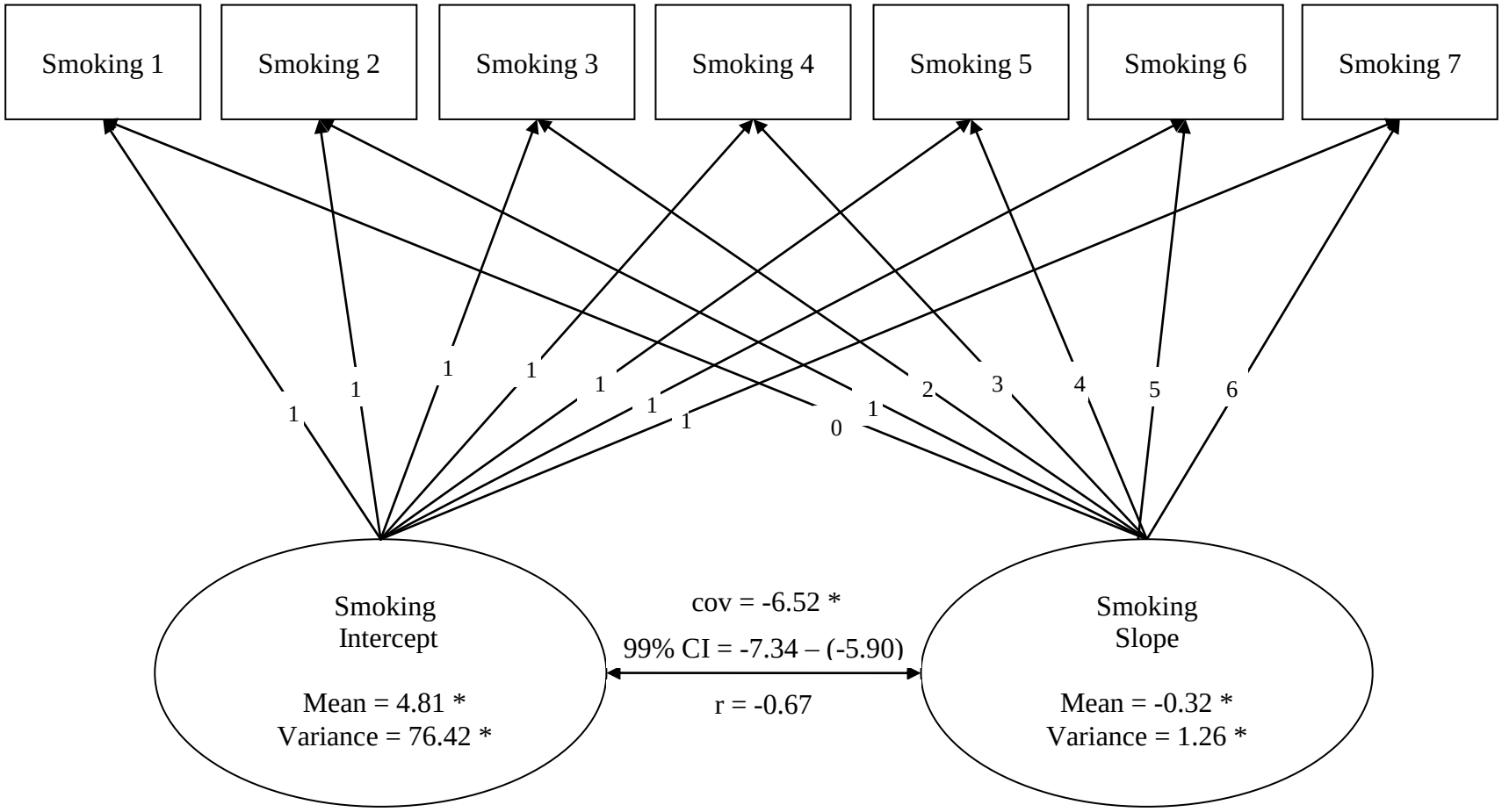
As depicted in Table 18, the linear model for smoking demonstrated adequate to mediocre fit; CFI = 0.97, RMSEA = 0.09 (90% CI = 0.08 – 0.09), and SRMR = 0.03. Although a significant chi-square difference test, $X^2(4) = 1510.07$, $p < 0.01$, suggested the use of an additional growth factor, this analysis opted to utilize a linear model. Both the observed and estimated trajectories of smoking appear in Figure 8.

Figure 8: Observed and Estimated Trajectories of Smoking



In this sample of Canadians, the average number of cigarettes smoked per day in 1994/1995 was 4.81 (99% CI = 4.64 – 5.01, $p < 0.01$) (Figure 9). A significant negative slope ($p < 0.01$) revealed that Canadians decreased their tobacco use by 0.32 cigarettes per day (99% CI = -0.35 – [-0.29]) biennially. Both the intercept and slope for smoking reported significant variances suggesting inter-individual variability. A significant negative covariance (cov = -6.52, 99% CI = -7.34 – [-5.90], $p < 0.01$) implied that Canadians who smoked a greater number of cigarettes per day in 1994/1995 reported a greater or steeper decline in tobacco use in subsequent cycles compared to their counterparts who smoked a lower quantity of cigarettes per day in 1994/1995. A strong intercept-slope relationship ($r = -0.67$) was observed for smoking.

Figure 9: Linear Growth Curve Model of Smoking (n = 15,112)



cov: Covariance; CI: Confidence Interval; r: Correlation.
99% Confidence intervals correspond to the covariance. Factor loadings were predetermined.
* Significant at $p \leq 0.01$.

4.6 Parallel Process Latent Growth Curve Models:

Once the trajectory of the three unconditional growth curve models was established, cross-behavioural covariances and correlations were estimated by simultaneously evaluating health behaviours using parallel process latent growth curve models. In total, three parallel process latent growth curve models were developed: alcohol consumption and leisure-time physical activity energy expenditure, leisure-time physical activity energy expenditure and smoking, and alcohol consumption and smoking.

4.6.1 Alcohol Consumption and Leisure-Time Physical Activity Energy Expenditure:

A parallel process latent growth curve model was developed by utilizing the linear trajectories of alcohol consumption and leisure-time physical activity. As outlined in Table 18, this model demonstrated good fit of the longitudinal data; CFI = 0.97, RMSEA = 0.03 (90% CI = 0.03 – 0.04), and SRMR = 0.03. In Table 21, the correlation coefficients between alcohol consumption and leisure-time physical activity energy expenditure were positive and fairly consistent.

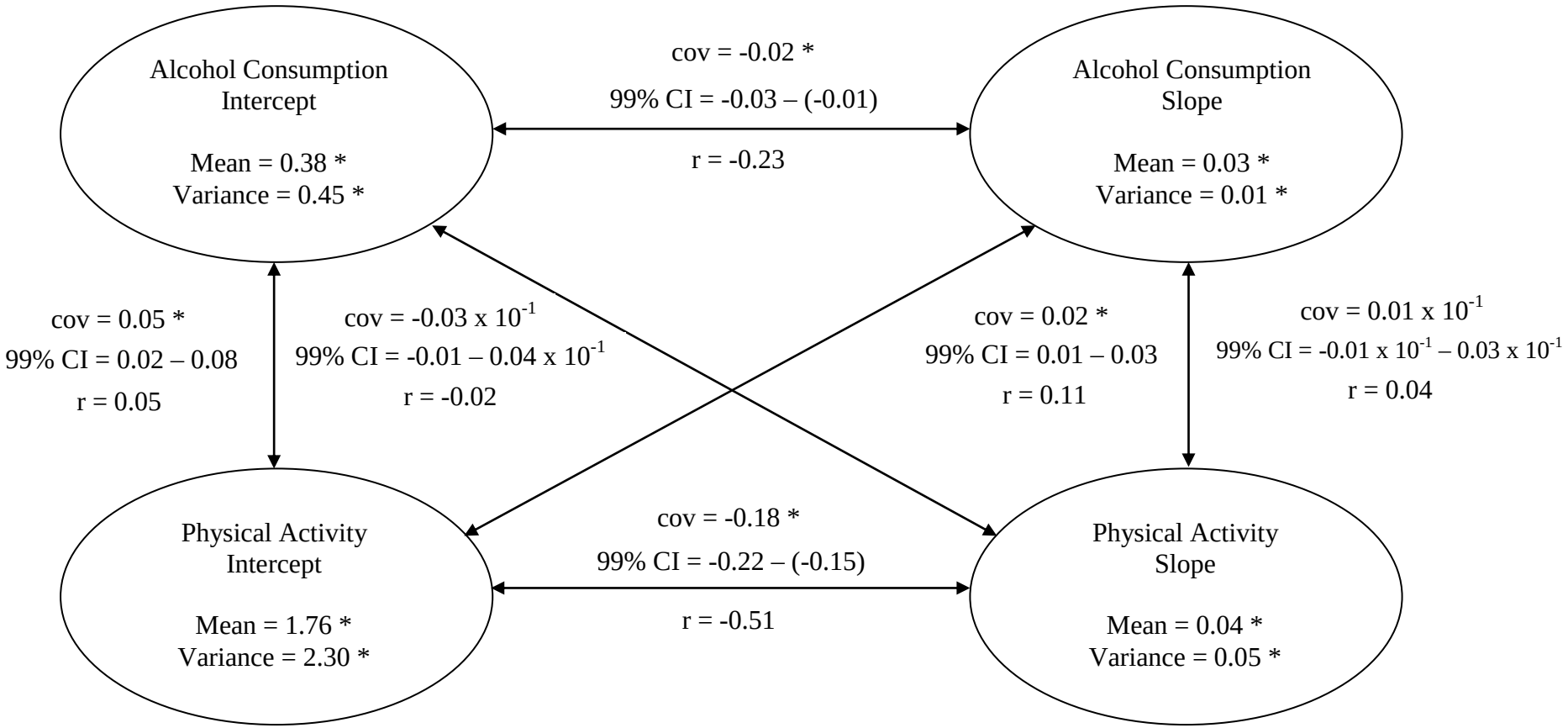
Table 21: Correlation Coefficients Between Alcohol Consumption and Leisure-Time Physical Activity

	Cycle 1: Alcohol	Cycle 2: Alcohol	Cycle 3: Alcohol	Cycle 4: Alcohol	Cycle 5: Alcohol	Cycle 6: Alcohol	Cycle 7: Alcohol
Cycle 1: Physical Activity	0.01	0.04	0.05	0.06	0.07	0.05	0.05
Cycle 2: Physical Activity	-0.02×10^{-1}	0.05	0.04	0.06	0.07	0.06	0.04
Cycle 3: Physical Activity	0.01	0.02	0.06	0.09	0.10	0.05	0.05
Cycle 4: Physical Activity	0.01	0.03	0.06	0.10	0.06	0.06	0.05
Cycle 5: Physical Activity	0.01	0.03	0.05	0.06	0.09	0.07	0.05
Cycle 6: Physical Activity	0.01	0.02	0.05	0.07	0.04	0.11	0.06
Cycle 7: Physical Activity	0.03	0.02	0.05	0.06	0.05	0.06	0.06

Depicted in Figure 10, the covariances within the behavioural domains of alcohol consumption and leisure-time physical activity energy expenditure were negative and remained significantly different from zero ($p < 0.01$). Only two of the four cross-behavioural covariances in Figure 10 were statistically significant. A significant covariance was observed between the intercept of alcohol consumption and the intercept of physical activity (cov = 0.05, 99% CI = 0.02 – 0.08, $p < 0.01$) suggesting that those Canadians who reported higher levels of energy expenditure in 1994/1995 also consumed higher quantities of alcohol. Conversely, Canadians participating in lower levels of physical activity in 1994/1995 also consumed lower quantities of alcohol. The second significant cross-behavioural covariance was observed between the intercept of physical activity and the slope of alcohol consumption (cov = 0.02, 99% CI = 0.01 – 0.03, $p < 0.01$). Consequently, the higher the initial status of physical activity, the steeper the positive trajectory of alcohol consumption became in subsequent cycles. On the other hand, Canadians who initially reported lower levels of leisure-time physical activity appeared to increase their consumption of alcohol at a slower rate over time. The other intercept-slope covariance between alcohol consumption and leisure-time physical activity was non-significant (cov = -0.03×10^{-1}, 99% CI = $-0.01 – 0.04 \times 10^{-1}$, $p > 0.01$). Of particular interest, the covariance between the slope of alcohol consumption and the

slope of physical activity did not reach statistical significance (cov = 0.01 x 10^{-1}, 99% CI = -0.01 x 10^{-1} – 0.03 x 10^{-1}, $p > 0.01$). Consequently, changes in physical activity, either positive or negative, were not significantly associated with changes in alcohol consumption. In conjunction with the covariances, correlations between latent variables were also reported in Figure 10. In general, these correlations were relatively weak. The only exception was observed for the intercept-slope correlation of leisure-time physical activity energy expenditure ($r = -0.51$). Each of the four latent variables continued to report significant variances suggesting inter-individual variability.

Figure 10: Parallel Process Model of Alcohol Consumption and Leisure-Time Physical Activity Energy Expenditure (n = 15,162)



cov: Covariance; CI: Confidence Interval; r: Correlation.
99% Confidence intervals correspond to the covariance.
* Significant at $p \leq 0.01$.

4.6.2 Leisure-Time Physical Activity Energy Expenditure and Smoking:

In Table 18, a parallel process latent growth curve model involving the linear trajectories of both leisure-time physical activity energy expenditure and smoking demonstrated good fit of the NPHS data; CFI = 0.97, RMSEA = 0.05 (90% CI = 0.05 – 0.05), and SRMR = 0.02. Correlations between physical activity and smoking for each data collection cycle were negative and decreased in strength over time (Table 22).

Table 22: Correlation Coefficients Between Leisure-Time Physical Activity and Smoking

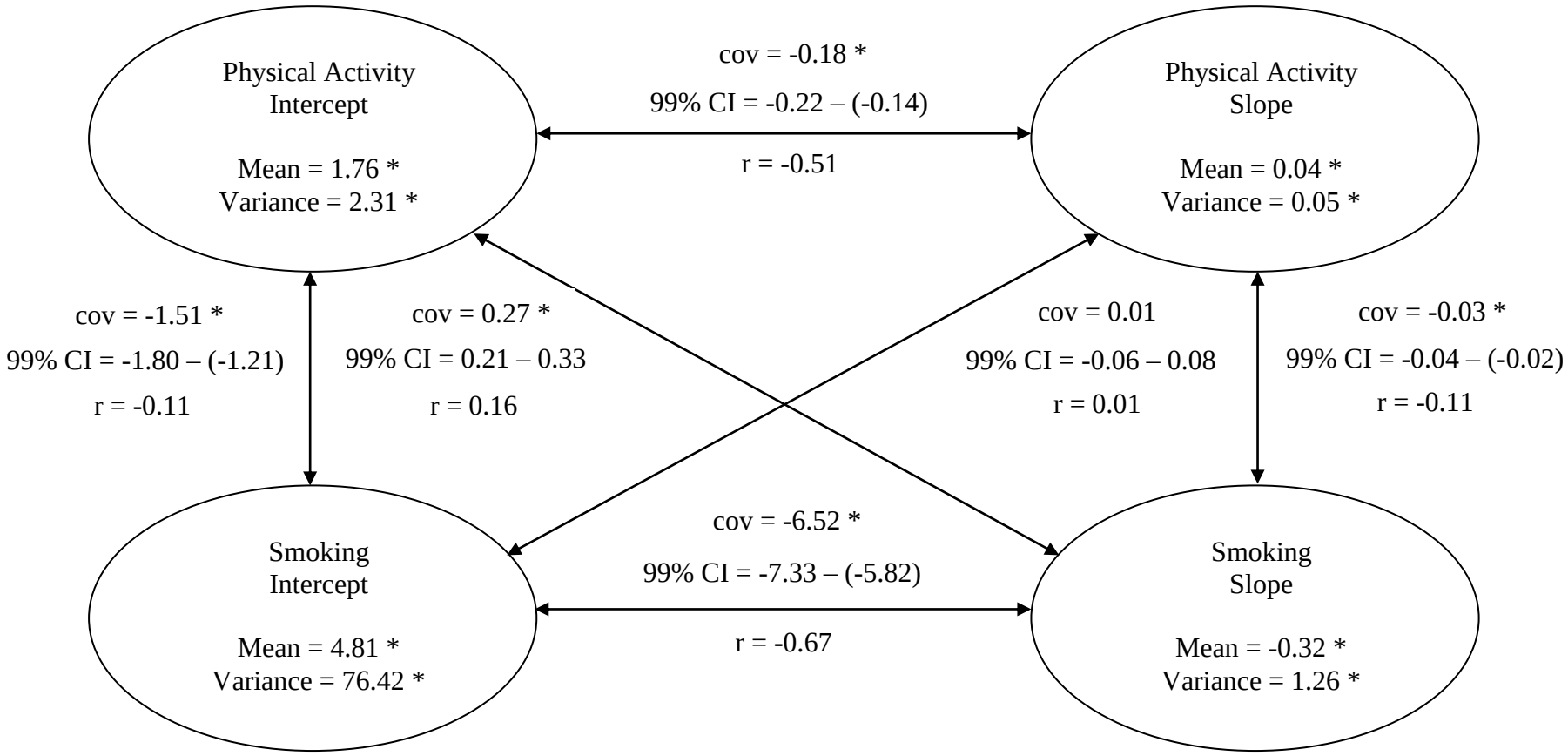
	Cycle 1: Physical Activity	Cycle 2: Physical Activity	Cycle 3: Physical Activity	Cycle 4: Physical Activity	Cycle 5: Physical Activity	Cycle 6: Physical Activity	Cycle 7: Physical Activity
Cycle 1: Smoking	-0.08	-0.08	-0.08	-0.08	-0.08	-0.09	-0.07
Cycle 2: Smoking	-0.06	-0.07	-0.07	-0.08	-0.08	-0.09	-0.06
Cycle 3: Smoking	-0.05	-0.06	-0.06	-0.08	-0.07	-0.09	-0.07
Cycle 4: Smoking	-0.02	-0.04	-0.03	-0.07	-0.06	-0.07	-0.06
Cycle 5: Smoking	-0.02	-0.03	-0.03	-0.05	-0.07	-0.07	-0.06
Cycle 6: Smoking	-0.04×10^{-1}	-0.01	-0.01	-0.03	-0.05	-0.07	-0.04
Cycle 7: Smoking	-0.02	†	-0.02	-0.04	-0.04	-0.05	-0.06

† Correlation was < 0.001.

Illustrated in Figure 11, the intercept-slope covariances for physical activity (cov = -0.18, 99% CI = -0.22 – [-0.14], $p < 0.01$) and smoking (cov = -6.52, 99% CI = -7.33 – [-5.82], $p < 0.01$) continued to be negative and significantly different from zero. Three of the four cross-behavioural covariances reached statistical significance. The significant negative covariance between the intercepts of leisure-time physical activity and smoking (cov = -1.51, 99% CI = -1.80 – [-1.21], $p < 0.01$) indicated that, in 1994/1995, Canadians participating in higher levels of physical activity either smoked fewer cigarettes per day or practiced abstinence from tobacco products. Alternatively, Canadians who demonstrated lower levels of physical activity were found to smoke a greater quantity of cigarettes. A significant positive covariance was observed between initial leisure-time physical activity levels and the rate of change in smoking (cov = 0.27, 99% CI = 0.21 – 0.33, $p < 0.01$) suggesting that Canadians who participated in higher levels of physical activity at baseline reported a flatter decline in the number of cigarettes smoked per day. The covariance between the intercept of smoking and the slope of physical activity was

the only cross-behavioural covariance that did not reach statistical significance (cov = 0.01, 99% CI = -0.06 – 0.08, $p > 0.01$). Of greatest importance was the covariance between the slopes of these two health behaviours. This relationship was negative and statistically significant (cov = -0.03, 99% CI = -0.04 – [-0.02], $p < 0.01$). Therefore, Canadians who made favourable changes in physical activity demonstrated a steeper decline in their smoking behaviour. On the other hand, Canadians who demonstrated a flatter positive trend in physical activity reported a flatter declining trajectory for daily tobacco use. Alongside these covariances, the correlations outlined in Figure 11 provided an indication of the strength of the relationship between latent variables. These cross-behavioural correlations suggested only weak associations between behaviours. Thus, changes in leisure-time physical activity energy expenditure appeared to be related, albeit weakly ($r = -0.11$), to changes in smoking. The significant variance in the latent variables of leisure-time physical activity and smoking demonstrated that the inclusion of covariates could assist in explaining the interrelationship of these two health behaviours.

Figure 11: Parallel Process Model of Leisure-Time Physical Activity Energy Expenditure and Smoking (n = 15,166)



cov: Covariance; CI: Confidence Interval; r: Correlation.
99% Confidence intervals correspond to the covariance.
* Significant at $p \leq 0.01$.

4.6.3 Alcohol Consumption and Smoking:

Table 18 indicates that the parallel process latent growth curve model for the linear trajectories of alcohol consumption and smoking behaviour fit the data well; CFI = 0.97, RMSEA = 0.05 (90% CI = 0.05 – 0.05), and SRMR = 0.03. In Table 23, the correlation coefficients between alcohol consumption and smoking were positive.

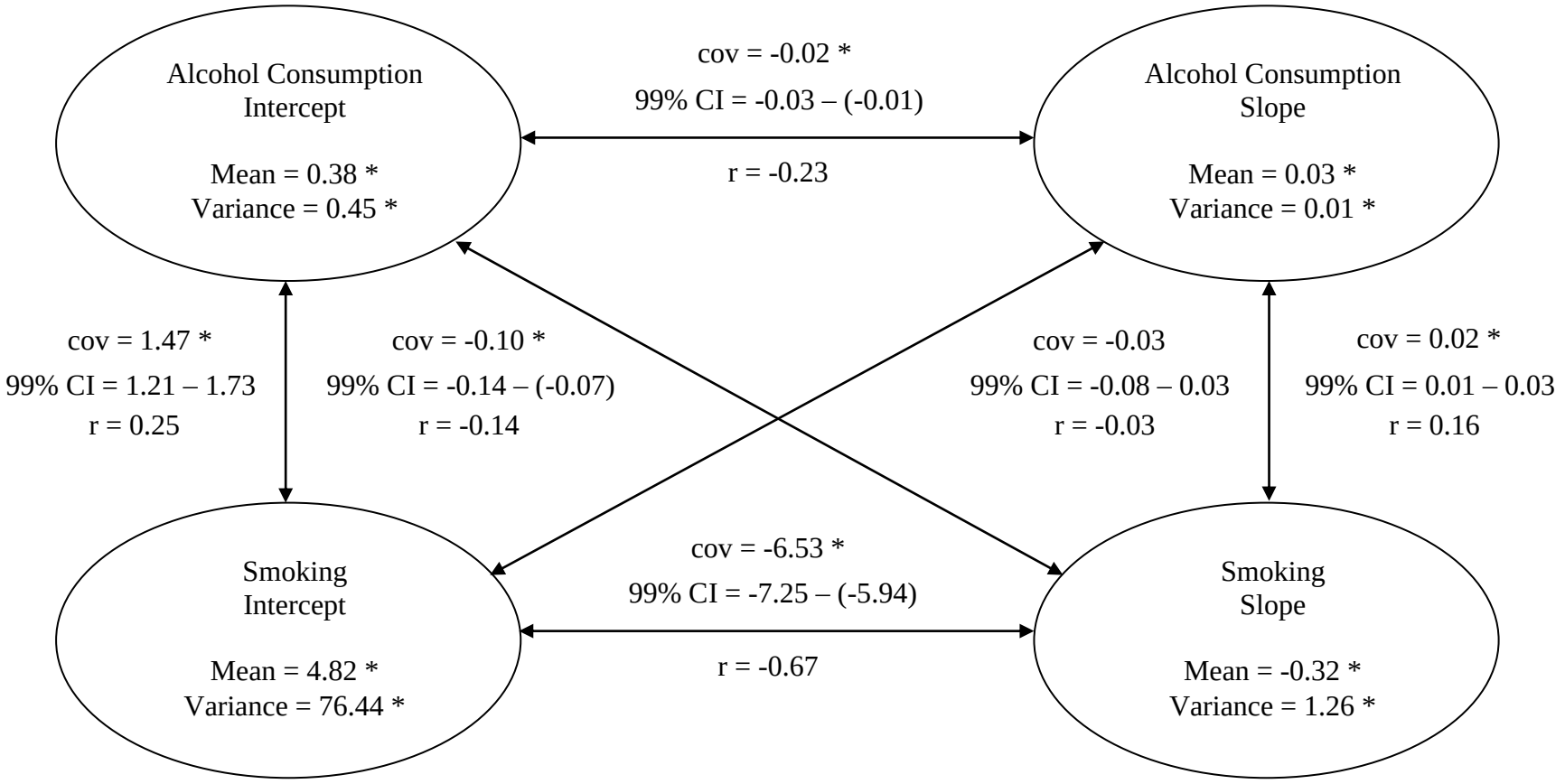
Table 23: Correlation Coefficients Between Alcohol Consumption and Smoking

	Cycle 1: Alcohol	Cycle 2: Alcohol	Cycle 3: Alcohol	Cycle 4: Alcohol	Cycle 5: Alcohol	Cycle 6: Alcohol	Cycle 7: Alcohol
Cycle 1: Smoking	0.19	0.16	0.13	0.12	0.10	0.13	0.16
Cycle 2: Smoking	0.17	0.18	0.15	0.14	0.13	0.14	0.19
Cycle 3: Smoking	0.17	0.17	0.19	0.15	0.15	0.15	0.17
Cycle 4: Smoking	0.16	0.15	0.15	0.18	0.17	0.15	0.19
Cycle 5: Smoking	0.16	0.15	0.16	0.17	0.18	0.16	0.19
Cycle 6: Smoking	0.15	0.15	0.16	0.15	0.18	0.17	0.19
Cycle 7: Smoking	0.15	0.14	0.14	0.15	0.19	0.18	0.19

Figure 12 illustrates the parallel process latent growth curve model for alcohol consumption and smoking behaviour. As observed in the unconditional growth curve models, the intercept-slope covariances for alcohol consumption and smoking remained negative and significantly different from zero ($p < 0.01$). Once again, three of the four cross-behavioural covariances reached statistical significance. The intercept-intercept covariance between alcohol consumption and smoking was positive and significant (cov = 1.47, 99% CI = 1.21 – 1.73, $p < 0.01$). This significant covariance suggested that Canadians who initially consumed higher quantities of alcohol also smoked a greater number of cigarettes. Alternatively, Canadians who initially consumed lower levels of alcohol reported smoking fewer cigarettes on a daily basis. The significant negative covariance between the intercept of alcohol consumption and rate of change for smoking (cov = -0.10, 99% CI = -0.14 – [-0.07], $p < 0.01$) suggested that those Canadians who consumed higher levels of alcohol in 1994/1995 reported a faster decline in tobacco use over subsequent cycles. However, Canadians who drank smaller quantities of alcohol per day reported flatter declines in daily cigarette consumption. The cross-behavioural covariance between the intercept of smoking and the slope of alcohol consumption was not statistically significant (cov = -0.03, 99% CI = -0.08 – 0.03, $p > 0.01$). The slope-

slope covariance between alcohol consumption and smoking was significant (cov = 0.02, 99% CI = 0.01 – 0.03, $p < 0.01$). This suggested that Canadians who increased their alcohol consumption also reported a slower or flatter decline in daily cigarette use. Alternatively, as the positive trajectory in the consumption of alcohol became shallower, the declining trend in smoking behaviour was steeper. Although changes in alcohol consumption were significantly related to changes in smoking behaviour, it is important to consider that this correlation was weak ($r = 0.16$). Significant variances in the latent variables of alcohol consumption and smoking suggested inter-individual variability.

Figure 12: Parallel Process Model of Alcohol Consumption and Smoking (n = 15,166)



cov: Covariance; CI: Confidence Interval; r: Correlation.
99% Confidence intervals correspond to the covariance.
* Significant at $p \leq 0.01$.

4.7 Demographic Covariates:

In an attempt to determine how specific demographic characteristics may influence the interrelationship of multiple health behaviours, both time-invariant and time-varying covariates were individually incorporated into each parallel process latent growth curve model. Time-invariant covariates included gender and age, while time-varying covariates consisted of marital status, education, income adequacy, and BMI. The effect of each covariate on the interrelationship of multiple health behaviours is discussed in subsequent sections. Multiple imputation was employed to replace missing values with plausible responses for each of the time-varying covariates.

4.7.1 Gender:

Fit indices in Table 24 suggest that the inclusion of gender within each of the three parallel process growth curve models fit the data well; alcohol consumption and leisure-time physical activity energy expenditure (CFI = 0.97, RMSEA = 0.03 [90% CI = 0.03 – 0.03], and SRMR = 0.03), leisure-time physical activity energy expenditure and smoking (CFI = 0.97, RMSEA = 0.05 [90% CI = 0.05 – 0.05], and SRMR = 0.02), and alcohol consumption and smoking (CFI = 0.97, RMSEA = 0.05 [90% CI = 0.05 – 0.05], and SRMR = 0.03).

Table 24: Fit Indices for Parallel Process Models Adjusted for Time-Invariant Covariates

	X^2 (df)	CFI	RMSEA	90% CI for RMSEA	SRMR
Gender:					
Alcohol Consumption & Physical Activity	1637.83 (101) *	0.97	0.03	0.03 – 0.03	0.03
Physical Activity & Smoking	3479.41 (101) *	0.97	0.05	0.05 – 0.05	0.02
Alcohol Consumption & Smoking	3681.35 (101) *	0.97	0.05	0.05 – 0.05	0.03
Chronological Age:					
Alcohol Consumption & Physical Activity	1675.09 (101) *	0.97	0.03	0.03 – 0.03	0.03
Physical Activity & Smoking	3565.57 (101) *	0.97	0.05	0.05 – 0.05	0.02
Alcohol Consumption & Smoking	3775.27 (101) *	0.97	0.05	0.05 – 0.05	0.03

* Significant at $p \leq 0.01$.

Initially, Canadian females demonstrated behaviours that were relatively healthier compared to their male counterparts (Table 25). In 1994/1995, women reported significantly lower levels of alcohol consumption, leisure-time physical activity energy expenditure, and tobacco use. However, over subsequent data collection cycles, significant behavioural changes had begun to emerge. Table 25 revealed that women demonstrated a slower increase in alcohol consumption, a steeper rise in leisure-time physical activity, and a flatter decline in tobacco use. Table 25 also presents the gender adjusted correlations between latent variables for each of the three parallel process models. After accounting for gender, the strength of these correlations were consistent with those of the unadjusted parallel process models.

Table 25: Unstandardized Parameter Estimates and Correlations for Parallel Process Models Adjusted for Gender

	Gender
Alcohol Consumption & Physical Activity (n = 15,162)	
Latent Variables:	
Alcohol Consumption Intercept	-0.38 (-0.42 – [-0.35]) *
Alcohol Consumption Slope	-0.02 (-0.03 – [-0.01]) *
Physical Activity Intercept	-0.48 (-0.56 – [-0.41]) *
Physical Activity Slope	0.03 (0.02 – 0.05) *
Correlations:	
Alcohol Consumption Intercept & Alcohol Consumption Slope	-0.23
Physical Activity Intercept & Physical Activity Slope	-0.51
Alcohol Consumption Intercept & Physical Activity Intercept	0.05
Alcohol Consumption Intercept & Physical Activity Slope	-0.02
Alcohol Consumption Slope & Physical Activity Intercept	0.11
Alcohol Consumption Slope & Physical Activity Slope	0.04
Physical Activity & Smoking (n = 15,166)	
Latent Variables:	
Physical Activity Intercept	-0.48 (-0.57 – [-0.40]) *
Physical Activity Slope	0.03 (0.02 – 0.05) *
Smoking Intercept	-1.53 (-1.93 – [-1.21]) *
Smoking Slope	0.07 (0.01 – 0.13) *
Correlations:	
Physical Activity Intercept & Physical Activity Slope	-0.51
Smoking Intercept & Smoking Slope	-0.67
Physical Activity Intercept & Smoking Intercept	-0.11
Physical Activity Intercept & Smoking Slope	0.16
Physical Activity Slope & Smoking Intercept	0.01
Physical Activity Slope & Smoking Slope	-0.11
Alcohol Consumption & Smoking (n = 15,166)	
Latent Variables:	
Alcohol Consumption Intercept	-0.38 (-0.42 – [-0.35]) *
Alcohol Consumption Slope	-0.02 (-0.03 - [-0.01]) *
Smoking Intercept	-1.53 (-1.94 – [-1.18]) *
Smoking Slope	0.07 (0.01 - 0.13) *
Correlations:	
Alcohol Consumption Intercept & Alcohol Consumption Slope	-0.23
Smoking Intercept & Smoking Slope	-0.67
Alcohol Consumption Intercept & Smoking Intercept	0.25
Alcohol Consumption Intercept & Smoking Slope	-0.14
Alcohol Consumption Slope & Smoking Intercept	-0.03
Alcohol Consumption Slope & Smoking Slope	0.16

99% Confidence intervals are in parentheses.

* Significant at $p \leq 0.01$.

4.7.2 Chronological Age:

As demonstrated in Table 24, the addition of chronological age in each parallel process model fit the data well; alcohol consumption and leisure-time physical activity energy expenditure (CFI = 0.97, RMSEA = 0.03 [90% CI = 0.03 – 0.03], and SRMR = 0.03), leisure-time physical activity energy expenditure and smoking (CFI = 0.97, RMSEA = 0.05 [90% CI = 0.05 – 0.05], and SRMR = 0.02), and alcohol consumption and smoking (CFI = 0.97, RMSEA = 0.05 [90% CI = 0.05 – 0.05], and SRMR = 0.03).

As a time-invariant covariate, chronological age appeared to have a significant influence on the majority of latent variables. According to Table 26, older Canadians reported significantly lower initial levels of leisure-time physical activity and cigarettes smoked per day compared to their younger counterparts. Over time, healthier behavioural changes began to transpire among older Canadians as they exhibited a slower increase in alcohol consumption and a greater decline in tobacco use. A steeper rise in leisure-time physical activity was also observed for older Canadians. However this association was only identified in the leisure-time physical activity and smoking model. Unfortunately, each of the behavioural changes, although significant, were relatively small in magnitude. Also presented in Table 26 are the adjusted latent variable correlations. Adjusting for chronological age seemed to have little influence on the strength of the correlations between latent variables.

Table 26: Unstandardized Parameter Estimates and Correlations for Parallel Process Models Adjusted for Chronological Age

	Chronological Age
Alcohol Consumption & Physical Activity (n = 15,162)	
Latent Variables:	
Alcohol Consumption Intercept	-0.01×10^{-1} (-0.02×10^{-1} – †)
Alcohol Consumption Slope	-0.01×10^{-1} (-0.01×10^{-1} – [-0.01×10^{-1}]) *
Physical Activity Intercept	-0.02 (-0.03 – [-0.02]) *
Physical Activity Slope	0.01×10^{-1} († - 0.02×10^{-1})
Correlations:	
Alcohol Consumption Intercept & Alcohol Consumption Slope	-0.22
Physical Activity Intercept & Physical Activity Slope	-0.50
Alcohol Consumption Intercept & Physical Activity Intercept	0.04
Alcohol Consumption Intercept & Physical Activity Slope	-0.02
Alcohol Consumption Slope & Physical Activity Intercept	0.12
Alcohol Consumption Slope & Physical Activity Slope	0.04
Physical Activity & Smoking (n = 15,166)	
Latent Variables:	
Physical Activity Intercept	-0.02 (-0.03 – [-0.02]) *
Physical Activity Slope	0.01×10^{-1} (0.01×10^{-1} - 0.02×10^{-1}) *
Smoking Intercept	-0.02 (-0.03 – [-0.02]) *
Smoking Slope	-0.01 (-0.01 – [0.04×10^{-1}]) *
Correlations:	
Physical Activity Intercept & Physical Activity Slope	-0.50
Smoking Intercept & Smoking Slope	-0.66
Physical Activity Intercept & Smoking Intercept	-0.11
Physical Activity Intercept & Smoking Slope	0.17
Physical Activity Slope & Smoking Intercept	0.01
Physical Activity Slope & Smoking Slope	-0.11
Alcohol Consumption & Smoking (n = 15,166)	
Latent Variables:	
Alcohol Consumption Intercept	-0.01×10^{-1} (-0.02×10^{-1} - †)
Alcohol Consumption Slope	-0.01×10^{-1} (-0.01×10^{-1} – [-0.01×10^{-1}]) *
Smoking Intercept	-0.02 (-0.03 - [-0.02]) *
Smoking Slope	-0.01 (-0.01 – [-0.04×10^{-1}]) *
Correlations:	
Alcohol Consumption Intercept & Alcohol Consumption Slope	-0.22
Smoking Intercept & Smoking Slope	-0.66
Alcohol Consumption Intercept & Smoking Intercept	0.25
Alcohol Consumption Intercept & Smoking Slope	-0.13
Alcohol Consumption Slope & Smoking Intercept	-0.03
Alcohol Consumption Slope & Smoking Slope	0.16

99% Confidence intervals are in parentheses. † Confidence interval was < 0.001.

* Significant at $p \leq 0.01$.

4.7.3 Marital Status:

As a time-varying covariate, the addition of marital status to each parallel process model demonstrated good fit (Table 27). Although each model had reported an excessive X^2 value, the respective values for the CFI, RMSEA, and SRMR were within an acceptable range; alcohol consumption and leisure-time physical activity energy expenditure (CFI = 0.97, RMSEA = 0.02 [90% CI = 0.02 – 0.02], and SRMR = 0.03), leisure-time physical activity energy expenditure and smoking (CFI = 0.97, RMSEA = 0.03 [90% CI = 0.03 – 0.03], and SRMR = 0.03), and alcohol consumption and smoking (CFI = 0.97, RMSEA = 0.03 [90% CI = 0.03 – 0.03], and SRMR = 0.03).

Table 27: Fit Indices for Parallel Process Models Adjusted for Time-Varying Covariates

	X^2 (df)	CFI	RMSEA	90% CI for RMSEA	SRMR
Marital Status:					
Alcohol Consumption & Physical Activity	1347.97 (175) *	0.97	0.02	0.02 – 0.02	0.03
Physical Activity & Smoking	2678.26 (175) *	0.97	0.03	0.03 – 0.03	0.03
Alcohol Consumption & Smoking	2948.57 (175) *	0.97	0.03	0.03 – 0.03	0.03
Education:					
Alcohol Consumption & Physical Activity	396.28 (175) *	0.98	0.01	0.01 - 0.01	0.04
Physical Activity & Smoking	785.95 (175) *	0.97	0.02	0.01 – 0.02	0.05
Alcohol Consumption & Smoking	770.72 (175) *	0.97	0.02	0.01 – 0.02	0.04
Income Adequacy:					
Alcohol Consumption & PhysicalActivity	1269.57 (175) *	0.97	0.02	0.02 – 0.02	0.05
Physical Activity & Smoking	2438.89 (175) *	0.97	0.03	0.03 – 0.03	0.04
Alcohol Consumption & Smoking	2632.98 (175) *	0.97	0.03	0.03 – 0.03	0.04
BMI:					
Alcohol Consumption & PhysicalActivity	1088.35 (175) *	0.97	0.02	0.02 – 0.02	0.02
Physical Activity & Smoking	2190.19 (175) *	0.97	0.03	0.03 – 0.03	0.02
Alcohol Consumption & Smoking	2344.47 (175) *	0.97	0.03	0.03 – 0.03	0.02

* Significant at $p \leq 0.01$.

As outlined in Tables 28 through 30, marital status appeared to be a significant predictor of each health behaviour at nearly every cycle of the NPHS. Single and formerly married Canadians demonstrated greater levels of both alcohol consumption and tobacco use

during six of the seven cycles of the NPHS. Furthermore, single and formerly married Canadians also had a tendency to participate in significantly higher levels of leisure-time physical activity compared to their married or co-habiting counterparts.

Table 28: Unstandardized Parameter Estimates for the Alcohol Consumption and Physical Activity Parallel Process Model Adjusted for Time-Varying Covariates (n = 15,162)

	Marital Status	Education	Income Adequacy	BMI
Health Behaviours:				
Cycle 1: Alcohol Consumption	0.01 (0.01)	0.18 (0.01) *	0.09 (0.01) *	0.09 (0.01) *
Cycle 2: Alcohol Consumption	0.04 (0.01) *	0.14 (0.01) *	0.05 (0.01) *	0.06 (0.01) *
Cycle 3: Alcohol Consumption	0.08 (0.01) *	0.14 (0.01) *	0.06 (0.01) *	0.04 (0.01) *
Cycle 4: Alcohol Consumption	0.12 (0.02) *	0.09 (0.01) *	0.02 (0.01)	-0.02 (0.01)
Cycle 5: Alcohol Consumption	0.16 (0.02) *	0.10 (0.02) *	0.04 (0.02) *	0.02×10^{-1} (0.01)
Cycle 6: Alcohol Consumption	0.11 (0.02) *	0.07 (0.02) *	0.02×10^{-1} (0.02)	-0.08 (0.01) *
Cycle 7: Alcohol Consumption	0.16 (0.02) *	0.11 (0.02) *	0.06 (0.02) *	-0.01 (0.02)
Cycle 1: Physical Activity	0.57 (0.03) *	-0.09 (0.03) *	0.02 (0.03)	-0.23 (0.03) *
Cycle 2: Physical Activity	0.53 (0.03) *	-0.02 (0.03)	0.10 (0.03) *	-0.22 (0.03) *
Cycle 3: Physical Activity	0.45 (0.03) *	0.14 (0.03) *	0.22 (0.02) *	-0.10 (0.03) *
Cycle 4: Physical Activity	0.07 (0.03)	-0.09 (0.03) *	-0.01 (0.02)	-0.37 (0.02) *
Cycle 5: Physical Activity	0.22 (0.03) *	0.19 (0.03) *	0.28 (0.03) *	-0.16 (0.03) *
Cycle 6: Physical Activity	0.08 (0.04)	0.15 (0.04) *	0.22 (0.03) *	-0.27 (0.03) *
Cycle 7: Physical Activity	0.13 (0.04) *	0.36 (0.04) *	0.44 (0.04) *	-0.06 (0.03)

Standard errors are in parentheses.
* Significant at $p \leq 0.01$.

Table 29: Unstandardized Parameter Estimates for the Physical Activity and Smoking Parallel Process Model Adjusted for Time-Varying Covariates (n = 15,166)

	Marital Status	Education	Income Adequacy	BMI
Health Behaviours:				
Cycle 1: Physical Activity	0.57 (0.03) *	-0.11 (0.03) *	0.02 (0.03)	-0.22 (0.03) *
Cycle 2: Physical Activity	0.52 (0.03) *	-0.05 (0.03)	0.11 (0.03) *	-0.21 (0.03) *
Cycle 3: Physical Activity	0.45 (0.03) *	0.11 (0.03) *	0.22 (0.02) *	-0.09 (0.03) *
Cycle 4: Physical Activity	0.07 (0.03)	-0.11 (0.03) *	-0.01 (0.02)	-0.36 (0.02) *
Cycle 5: Physical Activity	0.22 (0.03) *	0.16 (0.03) *	0.28 (0.03) *	-0.15 (0.03) *
Cycle 6: Physical Activity	0.09 (0.03) *	0.13 (0.03) *	0.21 (0.03) *	-0.26 (0.03) *
Cycle 7: Physical Activity	0.14 (0.04) *	0.33 (0.04) *	0.43 (0.04) *	-0.05 (0.03)
Cycle 1: Smoking	-0.22 (0.11)	0.34 (0.12) *	-0.13 (0.09)	-0.16 (0.10)
Cycle 2: Smoking	0.28 (0.10) *	0.24 (0.11)	-0.04 (0.07)	-0.13 (0.09)
Cycle 3: Smoking	0.50 (0.09) *	0.17 (0.10)	† (0.06)	-0.18 (0.08)
Cycle 4: Smoking	0.70 (0.09) *	-0.05 (0.10)	-0.16 (0.06) *	-0.31 (0.07) *
Cycle 5: Smoking	0.58 (0.09) *	-0.40 (0.11) *	-0.44 (0.07) *	-0.64 (0.07) *
Cycle 6: Smoking	0.70 (0.10) *	-0.30 (0.12) *	-0.30 (0.08) *	-0.51 (0.08) *
Cycle 7: Smoking	0.83 (0.11) *	-0.39 (0.13) *	-0.28 (0.09) *	-0.39 (0.09) *

Standard errors are in parentheses.
* Significant at $p \leq 0.01$.
† Parameter estimate was < 0.001.

Table 30: Unstandardized Parameter Estimates for the Alcohol Consumption and Smoking Parallel Process Model Adjusted for Time-Varying Covariates (n = 15,166)

	Marital Status	Education	Income Adequacy	BMI
Health Behaviours:				
Cycle 1: Alcohol Consumption	0.04×10^{-1} (0.01)	0.20 (0.01) *	0.09 (0.01) *	0.09 (0.01) *
Cycle 2: Alcohol Consumption	0.03 (0.01) *	0.16 (0.01) *	0.06 (0.01) *	0.06 (0.01) *
Cycle 3: Alcohol Consumption	0.07 (0.01) *	0.16 (0.01) *	0.08 (0.01) *	0.04 (0.01) *
Cycle 4: Alcohol Consumption	0.12 (0.02) *	0.12 (0.02) *	0.03 (0.01) *	-0.02 (0.01)
Cycle 5: Alcohol Consumption	0.15 (0.02) *	0.12 (0.02) *	0.06 (0.02) *	† (0.01)
Cycle 6: Alcohol Consumption	0.10 (0.02) *	0.10 (0.02) *	0.02 (0.02)	-0.08 (0.02) *
Cycle 7: Alcohol Consumption	0.15 (0.02) *	0.14 (0.02) *	0.08 (0.02) *	-0.01 (0.02)
Cycle 1: Smoking	-0.22 (0.11)	0.41 (0.12) *	-0.19 (0.08)	-0.13 (0.10)
Cycle 2: Smoking	0.29 (0.10) *	0.31 (0.11) *	-0.08 (0.07)	-0.11 (0.09)
Cycle 3: Smoking	0.51 (0.09) *	0.24 (0.10)	-0.04 (0.06)	-0.18 (0.08)
Cycle 4: Smoking	0.72 (0.09) *	0.03 (0.10)	-0.20 (0.06) *	-0.31 (0.07) *
Cycle 5: Smoking	0.60 (0.09) *	-0.31 (0.11) *	-0.48 (0.07) *	-0.64 (0.07) *
Cycle 6: Smoking	0.73 (0.10) *	-0.20 (0.12)	-0.33 (0.08) *	-0.51 (0.08) *
Cycle 7: Smoking	0.87 (0.11) *	-0.28 (0.13)	-0.30 (0.09) *	-0.40 (0.09) *

Standard errors are in parentheses.
* Significant at $p \leq 0.01$.
† Parameter estimate was < 0.001.

Table 31 presents the covariances between latent variables that were adjusted for the previously described time-varying covariates: marital status, education, income adequacy, and BMI. Those covariances that were significant in the unadjusted models remained statistically significant after adjusting for marital status. As shown in Table 32, accounting for marital status did not substantially attenuate the strength of the correlations between latent variables as these findings were similar to the unadjusted correlations. Therefore, it appears that marital status had little influence on the co-variation between health behaviours.

Table 31: Covariances Between Latent Variables Adjusted for Time-Varying Covariates

	Marital Status	Education	Income Adequacy	BMI
Alcohol Consumption and Physical Activity (n = 15,162):				
Alcohol Intercept & Alcohol Slope	-0.02 (0.03 x 10^{-1}) *	-0.02 (0.03 x 10^{-1}) *	-0.02 (0.03 x 10^{-1}) *	-0.02 (0.03 x 10^{-1}) *
Physical Activity Intercept & Physical Activity Slope	-0.16 (0.01) *	-0.18 (0.01) *	-0.18 (0.01) *	-0.18 (0.01) *
Alcohol Intercept & Physical Activity Intercept	0.05 (0.01) *	0.05 (0.01) *	0.04 (0.01) *	0.05 (0.01) *
Alcohol Intercept & Physical Activity Slope	-0.03 x 10^{-1} (0.03 x 10^{-1})	-0.04 x 10^{-1} (0.03 x 10^{-1})	-0.01 (0.03 x 10^{-1})	-0.03 x 10^{-1} (0.03 x 10^{-1})
Alcohol Slope & Physical Activity Intercept	0.02 (0.03 x 10^{-1}) *	0.02 (0.03 x 10^{-1}) *	0.02 (0.03 x 10^{-1}) *	0.02 (0.03 x 10^{-1}) *
Alcohol Slope & Physical Activity Slope	0.01 x 10^{-1} (0.01 x 10^{-1})	0.01 x 10^{-1} (0.01 x 10^{-1})	0.01 x 10^{-1} (0.01 x 10^{-1})	0.01 x 10^{-1} (0.01 x 10^{-1})
Physical Activity and Smoking (n = 15,166):				
Physical Activity Intercept & Physical Activity Slope	-0.16 (0.01) *	-0.18 (0.01) *	-0.18 (0.01) *	-0.18 (0.01) *
Smoking Intercept & Smoking Slope	-6.56 (0.27) *	-6.58 (0.27) *	-6.54 (0.27) *	-6.52 (0.27) *
Physical Activity Intercept & Smoking Intercept	-1.56 (0.12) *	-1.57 (0.13) *	-1.51 (0.12) *	-1.51 (0.12) *
Physical Activity Intercept & Smoking Slope	0.26 (0.02) *	0.28 (0.02) *	0.28 (0.02) *	0.27 (0.02) *
Physical Activity Slope & Smoking Intercept	0.02 (0.03)	0.04 (0.03)	0.03 (0.03)	0.01 (0.03)
Physical Activity Slope & Smoking Slope	-0.03 (0.01) *	-0.03 (0.01) *	-0.03 (0.01) *	-0.03 (0.01) *
Alcohol Consumption and Smoking (n = 15,166):				
Alcohol Intercept & Alcohol Slope	-0.02 (0.03 x 10^{-1}) *	-0.02 (0.03 x 10^{-1}) *	-0.02 (0.03 x 10^{-1}) *	-0.02 (0.03 x 10^{-1}) *
Smoking Intercept & Smoking Slope	-6.57 (0.26) *	-6.58 (0.27) *	-6.54 (0.26) *	-6.53 (0.26) *
Alcohol Intercept & Smoking Intercept	1.47 (0.09) *	1.52 (0.10) *	1.49 (0.09) *	1.46 (0.09) *
Alcohol Intercept & Smoking Slope	-0.10 (0.01) *	-0.10 (0.01) *	-0.10 (0.01) *	-0.10 (0.01) *
Alcohol Slope & Smoking Intercept	-0.04 (0.02)	-0.03 (0.02)	-0.03 (0.02)	-0.03 (0.02)
Alcohol Slope & Smoking Slope	0.02 (0.03 x 10^{-1}) *	0.02 (0.03 x 10^{-1}) *	0.02 (0.03 x 10^{-1}) *	0.02 (0.03 x 10^{-1}) *

Standard errors are in parentheses.

* Significant at $p \leq 0.01$.

Table 32: Correlations Between Latent Variables Adjusted for Time-Varying Covariates

	Marital Status	Education	Income Adequacy	BMI
Alcohol Consumption and Physical Activity (n = 15,162):				
Alcohol Consumption Intercept & Alcohol Consumption Slope	-0.23	-0.22	-0.23	-0.22
Physical Activity Intercept & Physical Activity Slope	-0.48	-0.51	-0.52	-0.50
Alcohol Consumption Intercept & Physical Activity Intercept	0.05	0.05	0.04	0.05
Alcohol Consumption Intercept & Physical Activity Slope	-0.02	-0.03	-0.03	-0.02
Alcohol Consumption Slope & Physical Activity Intercept	0.10	0.10	0.11	0.10
Alcohol Consumption Slope & Physical Activity Slope	0.05	0.05	0.04	0.04
Physical Activity and Smoking (n = 15,166):				
Physical Activity Intercept & Physical Activity Slope	-0.48	-0.51	-0.52	-0.50
Smoking Intercept & Smoking Slope	-0.67	-0.67	-0.67	-0.67
Physical Activity Intercept & Smoking Intercept	-0.12	-0.12	-0.11	-0.11
Physical Activity Intercept & Smoking Slope	0.16	0.16	0.16	0.16
Physical Activity Slope & Smoking Intercept	0.01	0.02	0.01	0.01
Physical Activity Slope & Smoking Slope	-0.10	-0.12	-0.11	-0.11
Alcohol Consumption and Smoking (n = 15,166):				
Alcohol Consumption Intercept & Alcohol Consumption Slope	-0.23	-0.22	-0.23	-0.22
Smoking Intercept & Smoking Slope	-0.67	-0.67	-0.67	-0.67
Alcohol Consumption Intercept & Smoking Intercept	0.25	0.26	0.26	0.25
Alcohol Consumption Intercept & Smoking Slope	-0.13	-0.14	-0.14	-0.13
Alcohol Consumption Slope & Smoking Intercept	-0.04	-0.03	-0.03	-0.03
Alcohol Consumption Slope & Smoking Slope	0.15	0.15	0.15	0.15

4.7.4 Education:

As illustrated in Table 27, the inclusion of education within each of the three parallel process models had shown adequate fit of the longitudinal data; alcohol consumption and leisure-time physical activity energy expenditure (CFI = 0.98, RMSEA = 0.01 [90% CI = 0.01 – 0.01], and SRMR = 0.04), leisure-time physical activity energy expenditure and smoking (CFI = 0.97, RMSEA = 0.02 [90% CI = 0.01 – 0.02], and SRMR = 0.05), and alcohol consumption and smoking (CFI = 0.97, RMSEA = 0.02 [90% CI = 0.01 – 0.02], and SRMR = 0.04).

Education appeared to be positively associated with both alcohol consumption and leisure-time physical activity during the majority of data collection cycles. Illustrated in Tables 28 through 30, higher levels of education were related to greater levels of alcohol consumption as well as leisure-time physical activity. Surprisingly, education seemed to have a lesser influence on tobacco use as a significant association between these two characteristics was only observed within half of the NPHS cycles (Tables 29 and 30). Furthermore, a positive association between education and smoking was observed during the early cycles, while this relationship became negative in the latter cycles.

Compared to the unadjusted findings, accounting for education had little effect on the significance level of the covariances (Table 31) and strength of the correlations (Table 32) in any of the three parallel process growth curve models. Although the strength of the correlations may have been slightly attenuated, the covariances preserved their respective directional association as well as level of significance.

4.7.5 Income Adequacy:

The fit indices in Table 27 revealed that adequate fit was obtained when income adequacy was incorporated into each of the following parallel process models; alcohol consumption and physical activity energy expenditure (CFI = 0.97, RMSEA = 0.02 [90% CI = 0.02 – 0.02], and SRMR = 0.05), physical activity energy expenditure and smoking (CFI = 0.97, RMSEA = 0.03 [90% CI = 0.03 – 0.03], and SRMR = 0.04), and alcohol consumption and smoking (CFI = 0.97, RMSEA = 0.03 [90% CI = 0.03 – 0.03], and SRMR = 0.04).

The effects of income adequacy on each health behaviour are outlined in Tables 28 through 30. Income adequacy was positively associated with both alcohol consumption and leisure-time physical activity suggesting that Canadians with a higher income adequacy consumed greater quantities of alcohol and participated in higher levels of leisure-time physical activity. The association between income adequacy and smoking appeared limited to the later cycles of the NPHS as those Canadians reporting higher income adequacies smoked in moderation or practiced abstinence (Tables 29 and 30).

Although income adequacy may have been a significant predictor of health behaviours, this demographic characteristic appeared to have no substantial effect on any of the behavioural covariances (Table 31) or correlations (Table 32). While income adequacy may have attenuated the strength of several correlations, any reduction appeared minimal. Furthermore, the statistical significance of the covariances was maintained. Therefore, covariances that were significant in the unadjusted models remained significant after controlling for income adequacy.

4.7.6 Body Mass Index:

In Table 27, the inclusion of BMI within each of the three parallel process models demonstrated adequate fit of the NPHS data; alcohol consumption and leisure-time physical activity energy expenditure (CFI = 0.97, RMSEA = 0.02 [90% CI = 0.02 – 0.02], and SRMR = 0.02), leisure-time physical activity energy expenditure and smoking (CFI = 0.97, RMSEA = 0.03 [90% CI = 0.03 – 0.03], and SRMR = 0.02), and alcohol consumption and smoking (CFI = 0.97, RMSEA = 0.03 [90% CI = 0.03 – 0.03], and SRMR = 0.02).

Depicted in Tables 28 and 30, body mass index demonstrated a significant positive association with alcohol consumption in the early cycles before changing to a significant negative association at the sixth cycle. This suggests that in the early cycles, Canadians who were overweight or obese consumed greater levels of alcohol. However, in the sixth cycle, higher BMI scores were related to lower quantities of alcohol consumption. Not surprisingly, Tables 28 and 29 revealed that body mass index was negatively associated with physical activity at nearly each cycle. Consequently, overweight and obese Canadians were less physically active compared to their underweight or normal weight

counterparts. Finally, in the mid and latter cycles of the NPHS, BMI was negatively related to smoking such that overweight or obese Canadians reported lower use of tobacco products compared to their underweight or normal weight counterparts (Tables 29 and 30).

Similar to the aforementioned demographic characteristics, Tables 31 and 32 illustrate that the effect of BMI on the behavioural covariances and correlations, respectively, were virtually negligible. Although a small number of the correlations may have experienced a slight attenuation after accounting for BMI, covariances that were significant in the unadjusted models remained statistically significant after adjusting for the BMI scores of Canadians.

Both time invariant and varying covariates were associated with health behaviours. However, these significant relationships did not appear to alter the covariances or correlations between health behaviours. Consequently, although demographic characteristics may predict the possession of unhealthy behaviours, these characteristics do not appear to either promote nor inhibit multiple behavioural changes.

4.8 Unconditional Growth Curve Model of Mastery:

The correlation coefficients between the repeated measures of mastery are outlined in Table 33. These correlations were positive and, as expected, demonstrated a tendency to decrease in size with the passage of time.

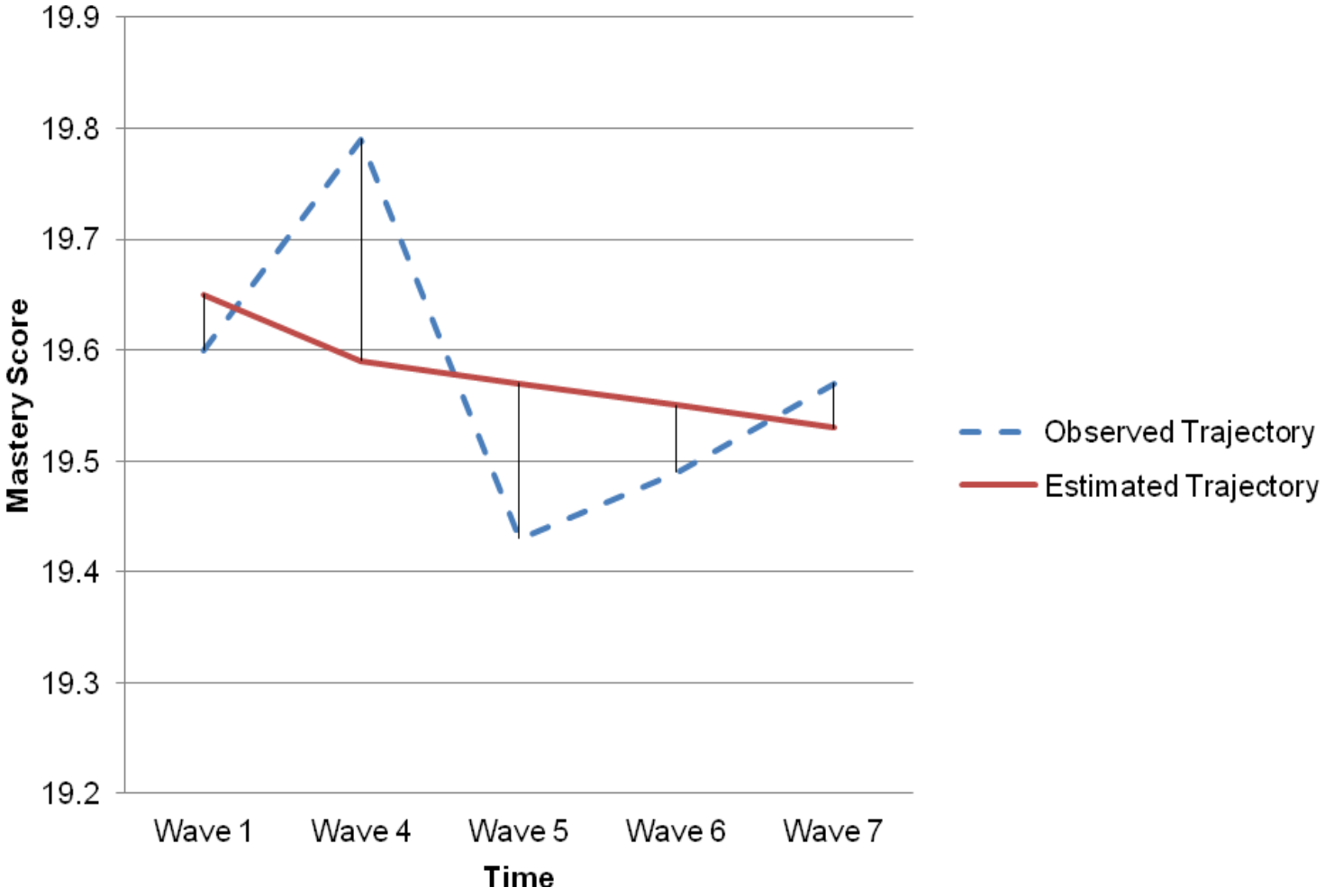
Table 33: Correlation Coefficients for Mastery

	Cycle 1: Mastery	Cycle 4: Mastery	Cycle 5: Mastery	Cycle 6: Mastery	Cycle 7: Mastery
Cycle 1: Mastery	1.00				
Cycle 4: Mastery	0.36	1.00			
Cycle 5: Mastery	0.38	0.46	1.00		
Cycle 6: Mastery	0.36	0.43	0.54	1.00	
Cycle 7: Mastery	0.37	0.42	0.53	0.56	1.00

Since mastery was not assessed among Canadians during 1996/1997 as well as 1998/1999, only five repeated measures were available to model its longitudinal trajectory. The observed and estimated trajectories of mastery are illustrated in Figure

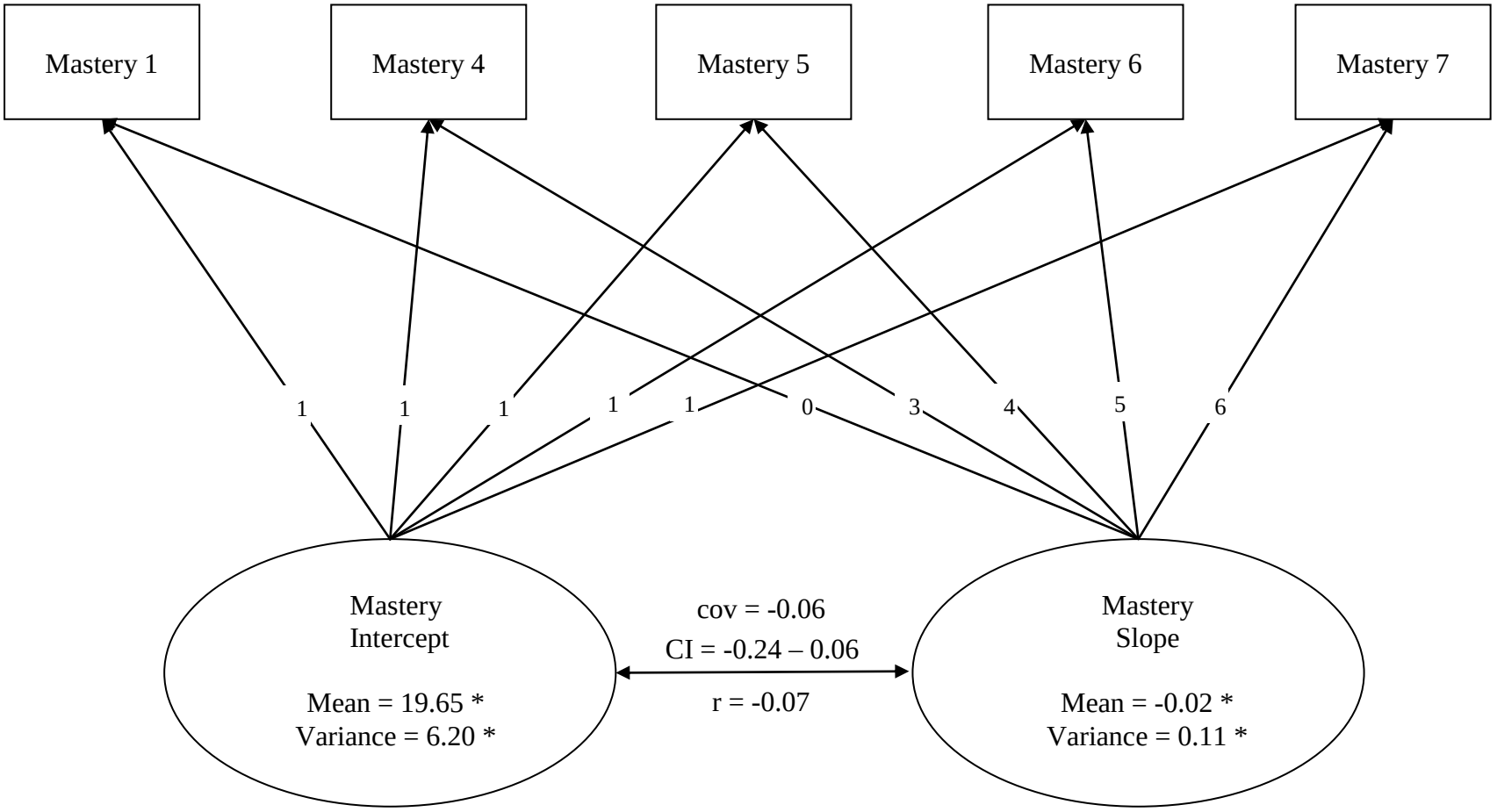
13. Modelling the linear trajectory of mastery demonstrated reasonable fit (CFI = 0.98, RMSEA = 0.04 [90% CI = 0.04 – 0.04], and SRMR = 0.07). The addition of a quadratic factor appeared to improve the fit of the mastery model; chi-square difference test $X^2(4) = 52.66$, $p < 0.001$. However, for interpretation reasons, a linear trajectory was chosen to represent mastery.

Figure 13: Observed and Estimated Trajectories of Mastery



According to Figure 14, Canadians reported an initial mastery score of 19.65 (99% CI = 19.55 – 19.73, $p < 0.01$) in 1994/1995. The mean mastery score had decreased by 0.02 (99% CI = $-0.04 – [-0.03 \times 10^{-1}]$, $p < 0.01$) at each cycle of the NPHS. This contradicted the findings in Table 13 in which mastery appeared to demonstrate relative stability. The significant variances of the two latent variables indicated inter-individual variability in both the intercept and slope of mastery. The negative covariance (cov = -0.06, 99% CI = -0.24 – 0.06) between the intercept and slope of mastery revealed that Canadians with higher initial scores in mastery decreased at a faster rate compared to their Canadian counterparts who initially demonstrated lower mastery scores. However, this negative covariance failed to reach statistical significance. A weak correlation ($r = -0.07$) between the intercept and slope of mastery was observed.

Figure 14: Linear Growth Curve Model of Mastery (n = 14,797)



cov: Covariance; CI: Confidence Interval; r: Correlation.
99% Confidence intervals correspond to the covariance. Factor loadings were predetermined.
* Significant at $p \leq 0.01$.

4.9 Mediating Effects of Mastery:

Parallel process latent growth curve models were used to evaluate the potential mediating effects of self perceived mastery on behavioural changes. In total, six parallel process models were developed; alcohol consumption and leisure-time physical activity energy expenditure, leisure-time physical activity energy expenditure and alcohol consumption, leisure-time physical activity energy expenditure and smoking, smoking and leisure-time physical activity energy expenditure, alcohol consumption and smoking, as well as smoking and alcohol consumption. Figure 3 represents an illustration of how each of the six models were created. In an attempt to simplify Figure 3, only parameter estimates and confidence intervals between latent slopes are reported in the following mediation figures. In accordance with the unconditional models developed in the previous sections, linear trajectories were used to depict each health behaviour as well as mastery.

4.9.1 Alcohol Consumption and Leisure-Time Physical Activity Energy Expenditure:

Outlined in Table 34, the mediation model involving alcohol consumption and leisure-time physical activity energy expenditure demonstrated good fit; CFI = 0.97, RMSEA = 0.03 (90% CI = 0.03 – 0.03), and SRMR = 0.03. Considering the substantial sample size (n = 15,162), a large and significant chi-square statistic, $X^2(165) = 2090.42$, $p < 0.01$, was expected.

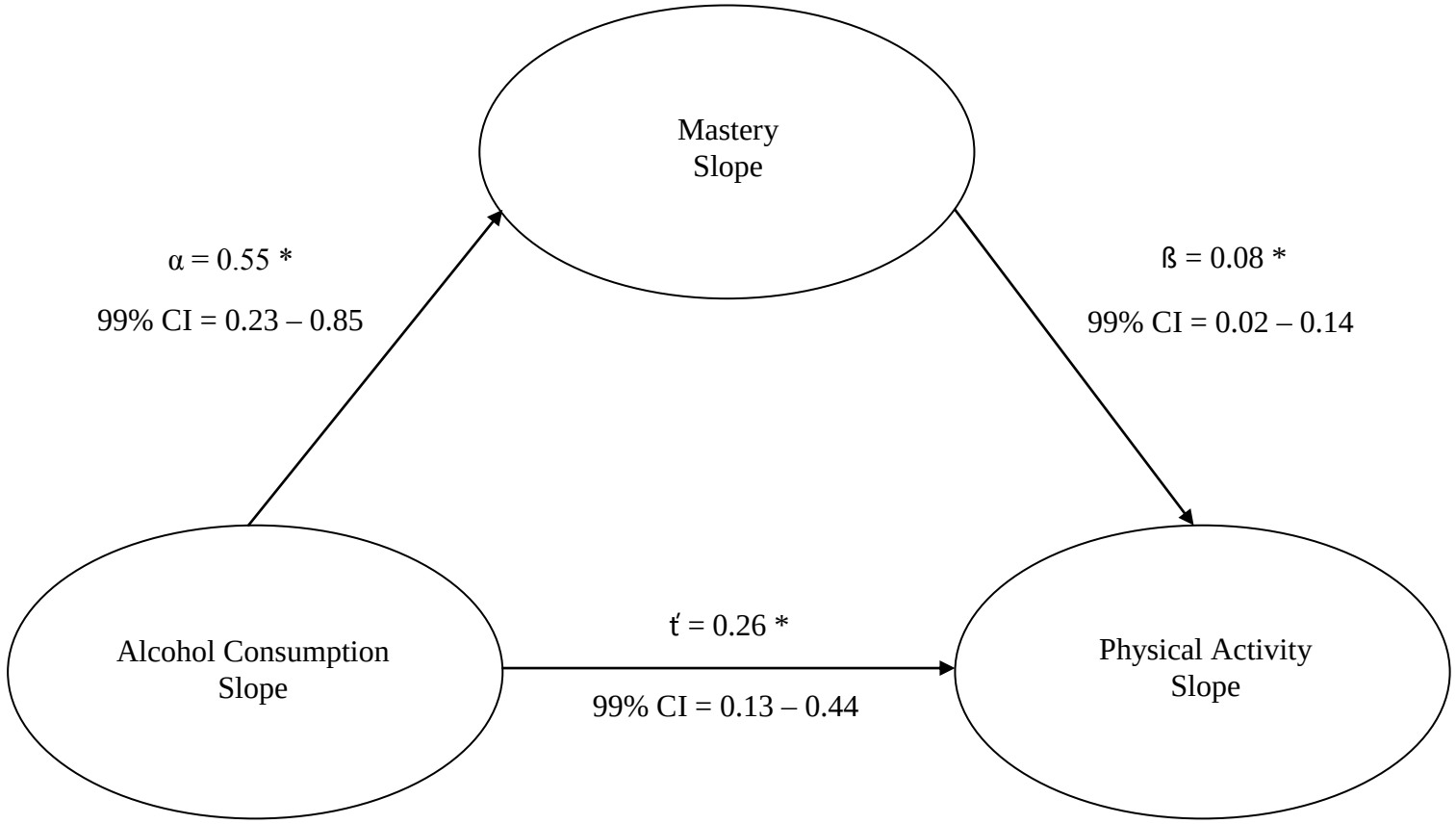
Table 34: Fit Indices for Mediation Parallel Process Models

	X^2 (df)	CFI	RMSEA	90% CI for RMSEA	SRMR
Alcohol Consumption & Physical Activity	2090.42 (165) *	0.97	0.03	0.03 - 0.03	0.03
Physical Activity & Alcohol Consumption	2070.98 (165) *	0.97	0.03	0.03 – 0.03	0.03
Physical Activity & Smoking	3944.85 (165) *	0.97	0.04	0.04 – 0.04	0.03
Smoking & Physical Activity	3979.51 (165) *	0.97	0.04	0.04 - 0.04	0.03
Alcohol Consumption & Smoking	4040.96 (165) *	0.97	0.04	0.04 – 0.04	0.03
Smoking & Alcohol Consumption	4046.09 (165) *	0.97	0.04	0.04 – 0.04	0.03

* Significant at $p \leq 0.01$

Illustrated in Figure 15, the slope of alcohol consumption had a positive and significant effect on the growth factor of mastery ($\alpha = 0.55$, 99% CI = 0.23 – 0.85, $p < 0.01$) indicating that as alcohol consumption increased, self perceived mastery also increased. The positive and significant effect of the slope of mastery on the slope of leisure-time physical activity energy expenditure ($ß = 0.08$, 99% CI = 0.02 – 0.14, $p < 0.01$) denoted that increases in mastery were associated with a steeper rise in leisure-time physical activity. The direct effect between alcohol consumption and leisure-time physical activity was also positive and significant ($t' = 0.26$, 99% CI = 0.13 - 0.44, $p < 0.01$) suggesting that increases in alcohol consumption resulted in an increase in leisure-time physical activity. The indirect effect revealed that the mediated effect of mastery was significant ($αß = 0.04$, 99% CI = 0.01 – 0.10, $p < 0.01$). Therefore, mastery appears to mediate the association between the slope of alcohol consumption and slope of leisure-time physical activity. However, since the direct effect remained significant, it appears that mastery acts as a partial mediator.

Figure 15: Mediation of Mastery in the Alcohol Consumption and Leisure-Time Physical Activity Energy Expenditure Model (n = 15,162)

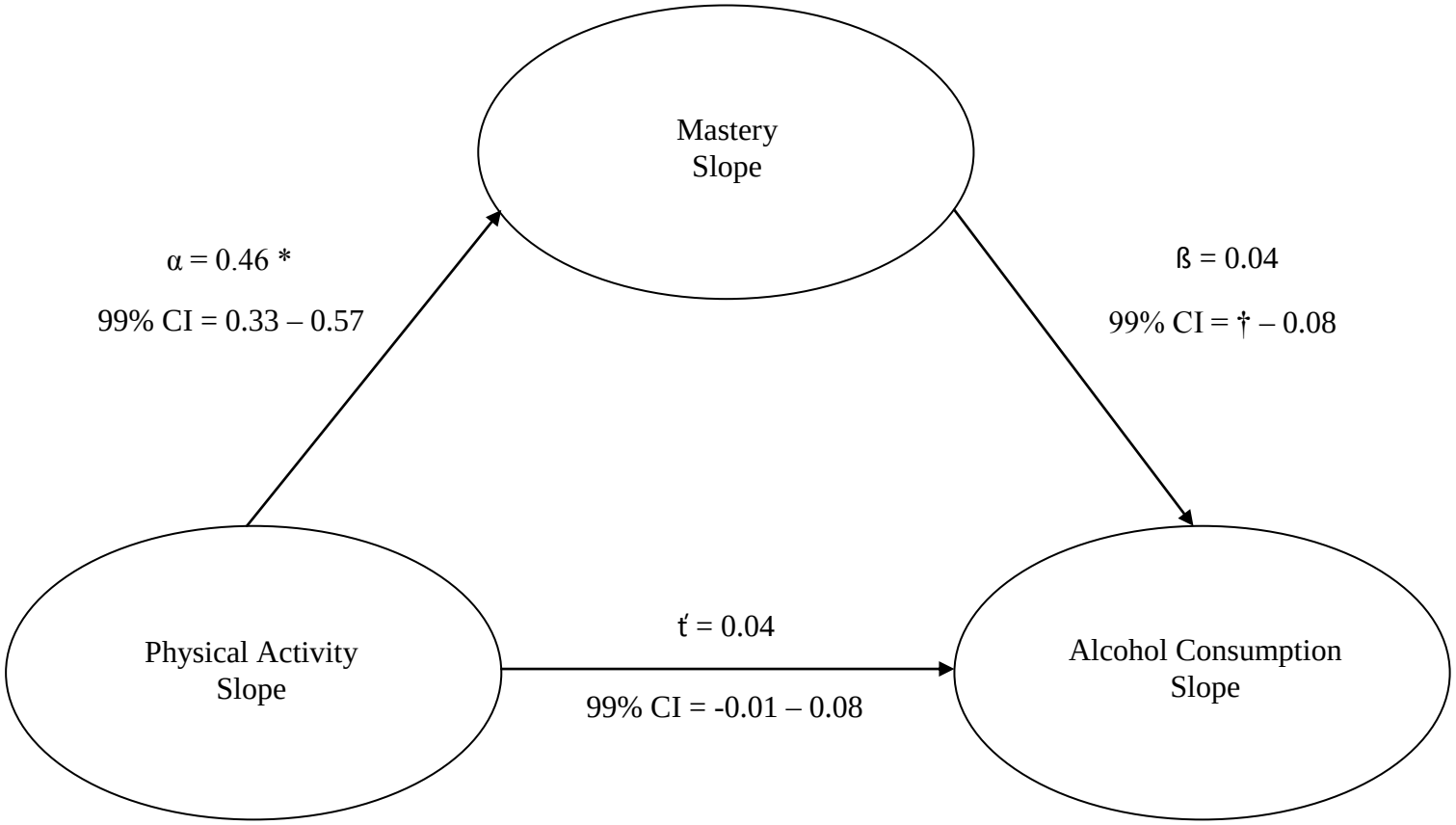


CI: Confidence Intervals.
Parameter estimates are unstandardized.
* Significant at $p \leq 0.01$.

4.9.2 Leisure-Time Physical Activity Energy Expenditure and Alcohol Consumption:

Evaluating the mediation of mastery in the relationship between leisure-time physical activity energy expenditure and alcohol consumption revealed good fit of the longitudinal data (Table 34); CFI = 0.97, RMSEA = 0.03 (90% CI = 0.03 – 0.03), and SRMR = 0.03. The large and significant chi-square statistic ($X^2[165] = 2070.98$, $p < 0.01$) was expected. In Figure 16, the positive and significant effect of the leisure-time physical activity slope on the slope of mastery ($\alpha = 0.46$, 99% CI = 0.33 – 0.57, $p < 0.01$) implies that increases in physical activity levels initiates an increase in the trajectory of self perceived mastery. The slope-slope coefficient between mastery and alcohol consumption was positive (ß = 0.04, 99% CI = † – 0.08). This association did not appear to be significant. The calculated indirect effect (αß = 0.02, 99% CI = † – 0.04) was not significant signifying that mediation, in the form of changes in mastery, was not present in the relationship between leisure-time physical activity energy expenditure and alcohol consumption. The direct effect of leisure-time physical activity on alcohol consumption also failed to reach statistical significance (ť = 0.04, 99% CI = -0.01 - 0.08).

Figure 16: Mediation of Mastery in the Leisure-Time Physical Activity Energy Expenditure and Alcohol Consumption Model (n = 15,162)

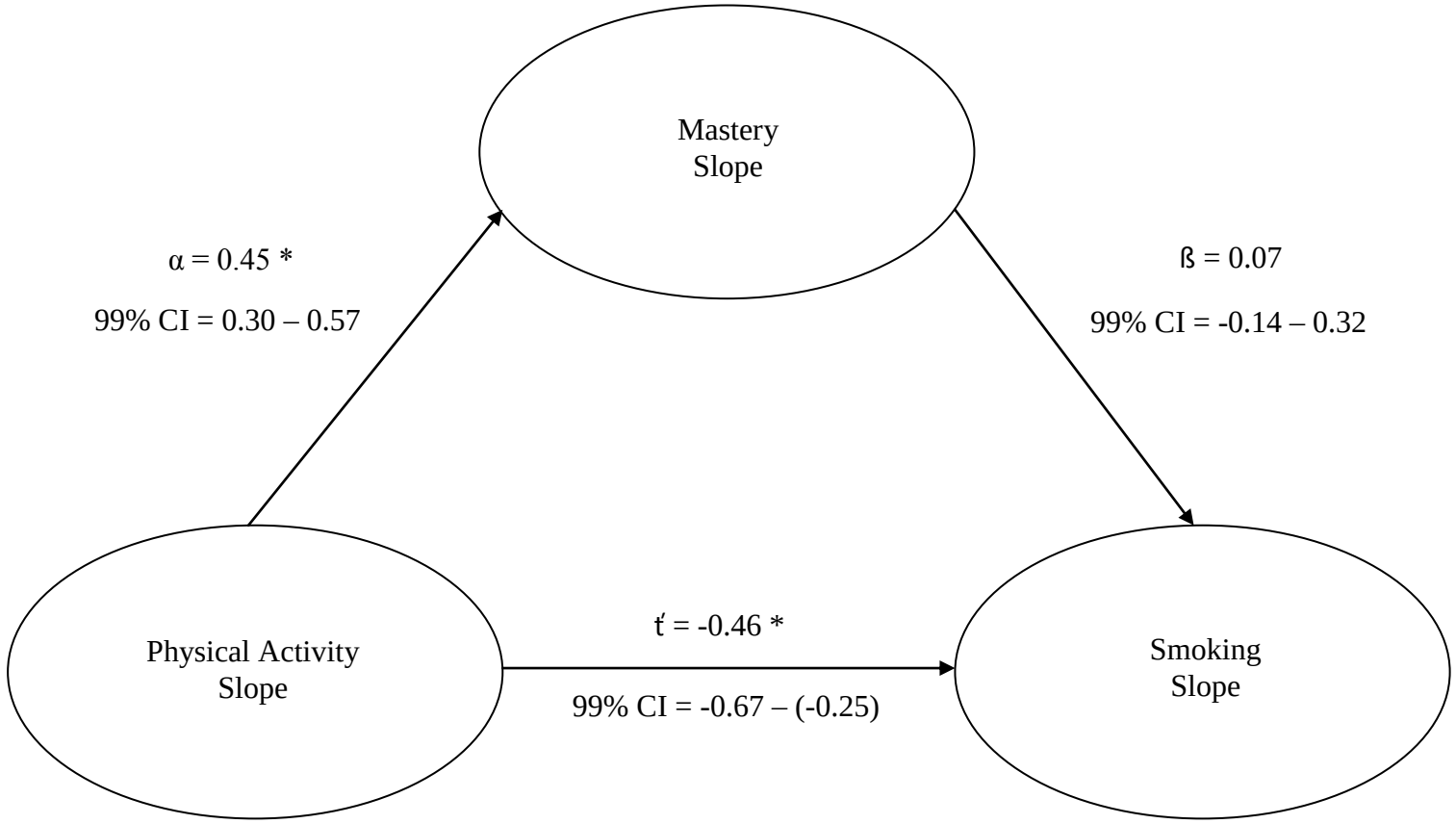


CI: Confidence Intervals.
Parameter estimates are unstandardized.
† Confidence interval was < 0.001.
* Significant at $p \leq 0.01$.

4.9.3 Leisure-Time Physical Activity Energy Expenditure and Smoking:

Illustrated in Table 34, the mediation model of leisure-time physical activity and smoking reported fit indices that suggested good model fit; CFI = 0.97, RMSEA = 0.04 (90% CI = 0.04 – 0.04), and SRMR = 0.03. Figure 17 presents the mediation model between leisure-time physical activity and smoking. The positive effect between the slope of leisure-time physical activity and slope of mastery (α = 0.45, 99% CI = 0.30 – 0.57, $p < 0.01$) indicated that increases in physical activity led to an increase in self perceived mastery. The non-significant effect of mastery on smoking (ß = 0.07, 99% CI = -0.14 – 0.32) suggested that changes in mastery did not influence changes in smoking behaviour. The mediated effect failed to reach statistical significance (αß = 0.03, 99% CI = -0.06 – 0.15) implying that the slope of mastery did not mediate the association of physical activity on smoking behaviour. The direct effect between the growth factors of physical activity and smoking was significant (ť = -0.46, 99% CI = -0.67 – [-0.25], $p < 0.01$). Therefore, an increase in physical activity resulted in a decrease in tobacco use.

Figure 17: Mediation of Mastery in the Leisure-Time Physical Activity Energy Expenditure and Smoking Model (n = 15,166)

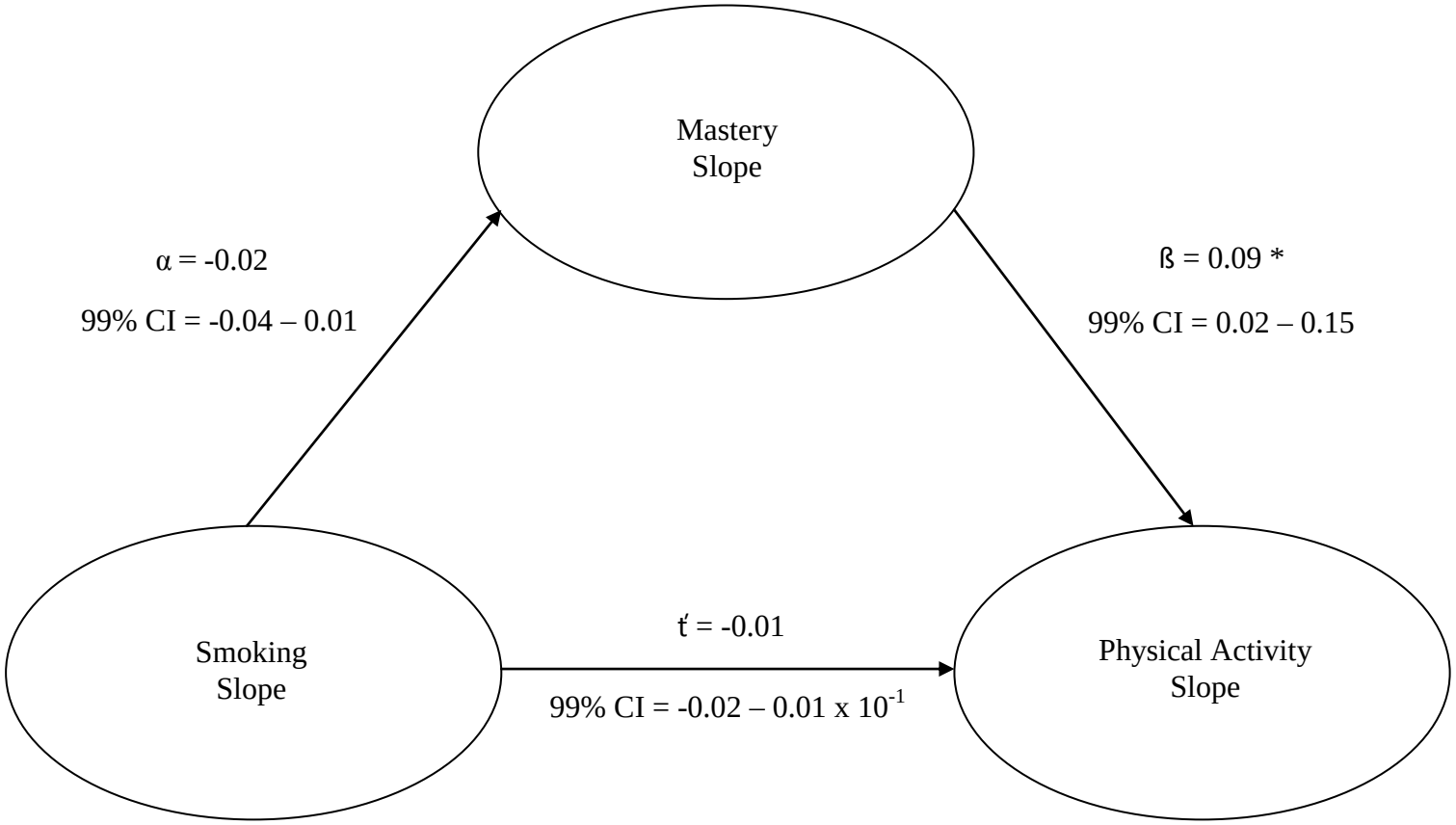


CI: Confidence Intervals.
Parameter estimates are unstandardized.
* Significant at $p \leq 0.01$.

4.9.4 Smoking and Leisure-Time Physical Activity Energy Expenditure:

Appropriate model fit was demonstrated by the mediation model of smoking and leisure-time physical activity (Table 34); CFI = 0.97, RMSEA = 0.04 (90% CI = 0.04 – 0.04), and SRMR = 0.03. In Figure 18, the effect of smoking on mastery was negative, but non-significant (α = -0.02, 99% CI = -0.04 – 0.01). Therefore, changes in smoking were unsuccessful in producing changes in mastery. However, changes in perceived mastery were found to influence changes in physical activity (β = 0.09, 99% CI = 0.02 – 0.15, $p < 0.01$). The estimated mediated effect was non-significant ($\alpha\beta = -0.01 \times 10^{-1}$, 99% CI = $-0.04 \times 10^{-1} – 0.01 \times 10^{-1}$) revealing that mastery did not mediate the relationship between smoking and leisure-time physical activity. The direct effect of smoking on physical activity also did not reach statistical significance ($\tau' = -0.01$, 99% CI = $-0.02 – 0.01 \times 10^{-1}$) implying that changes in smoking did not lead to changes in leisure-time physical activity energy expenditure.

Figure 18: Mediation of Mastery in the Smoking and Leisure-Time Physical Activity Energy Expenditure Model (n = 15,166)

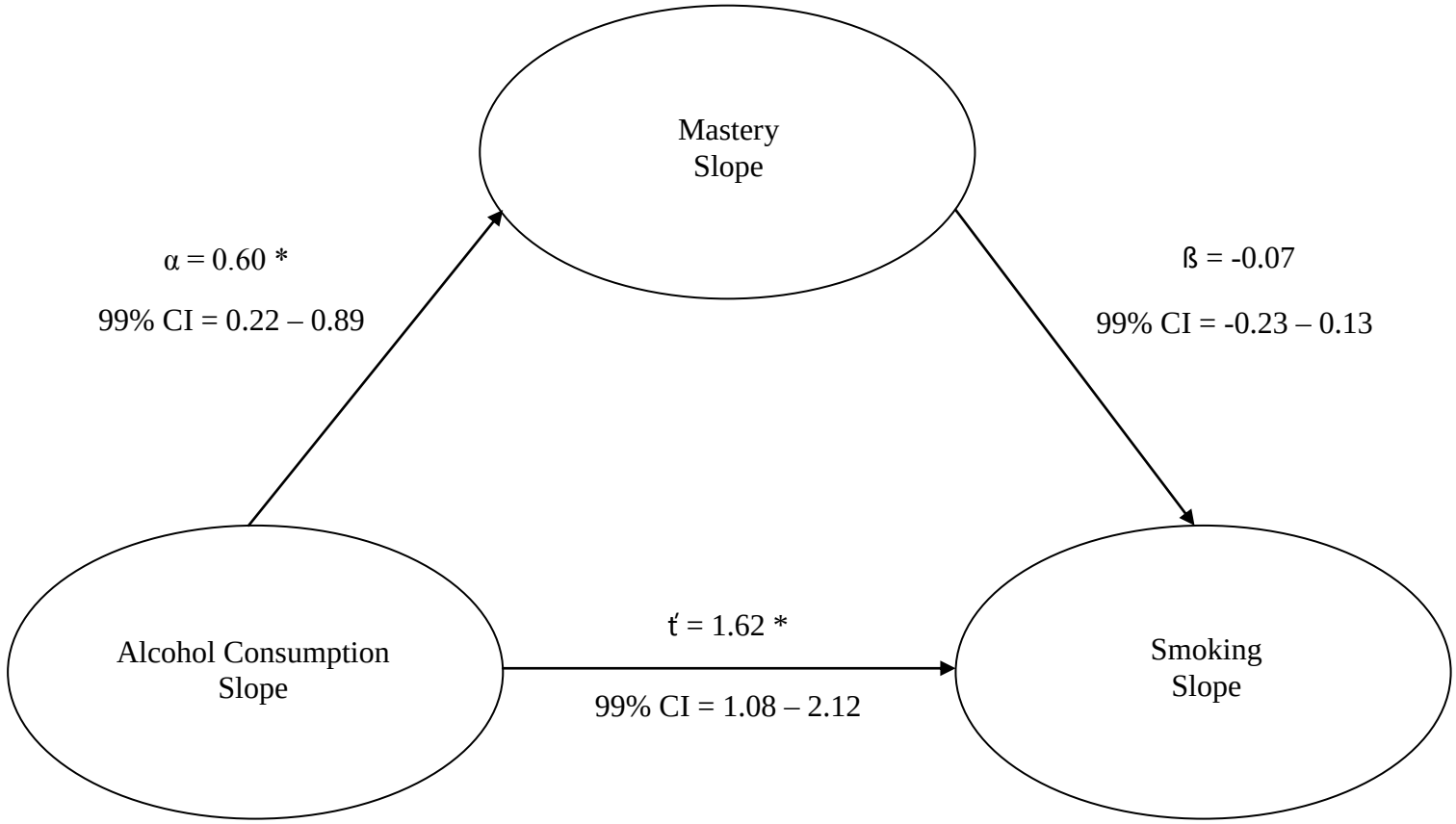


CI: Confidence Intervals.
Parameter estimates are unstandardized.
* Significant at $p \leq 0.01$.

4.9.5 Alcohol Consumption and Smoking:

According to Table 34, the fit indices for the mediation model involving alcohol consumption and smoking were within their respective cut-off criteria; CFI = 0.97, RMSEA = 0.04 (90% CI = 0.04 – 0.04), and SRMR = 0.03. The only exception was the significant chi-square statistic, $X^2(165) = 4040.96$, $p < 0.01$, which could be attributed to the substantial sample size of the study (n = 15,166). In Figure 19, the slope of alcohol consumption had a positive and significant effect on the slope of mastery ($\alpha = 0.60$, 99% CI = 0.22 – 0.89, $p < 0.01$) implying that an increase in the consumption of alcoholic beverages results in a flatter trajectory for self perceived mastery. Changes in mastery appeared to have no significant influence on changes in smoking (ß = -0.07, 99% CI = -0.23 - 0.13). The indirect effect was also non-significant (αß = -0.04, 99% CI = -0.18 – 0.07). Therefore, mastery did not emerge as a significant mediator in the relationship between alcohol consumption and smoking. The direct effect between the slope of alcohol consumption and the slope of smoking was significant (ť = 1.62, 99% CI = 1.08 – 2.12, $p < 0.01$) indicating that changes in alcohol consumption were associated with changes in tobacco use.

Figure 19: Mediation of Mastery in the Alcohol Consumption and Smoking Model (n = 15,166)

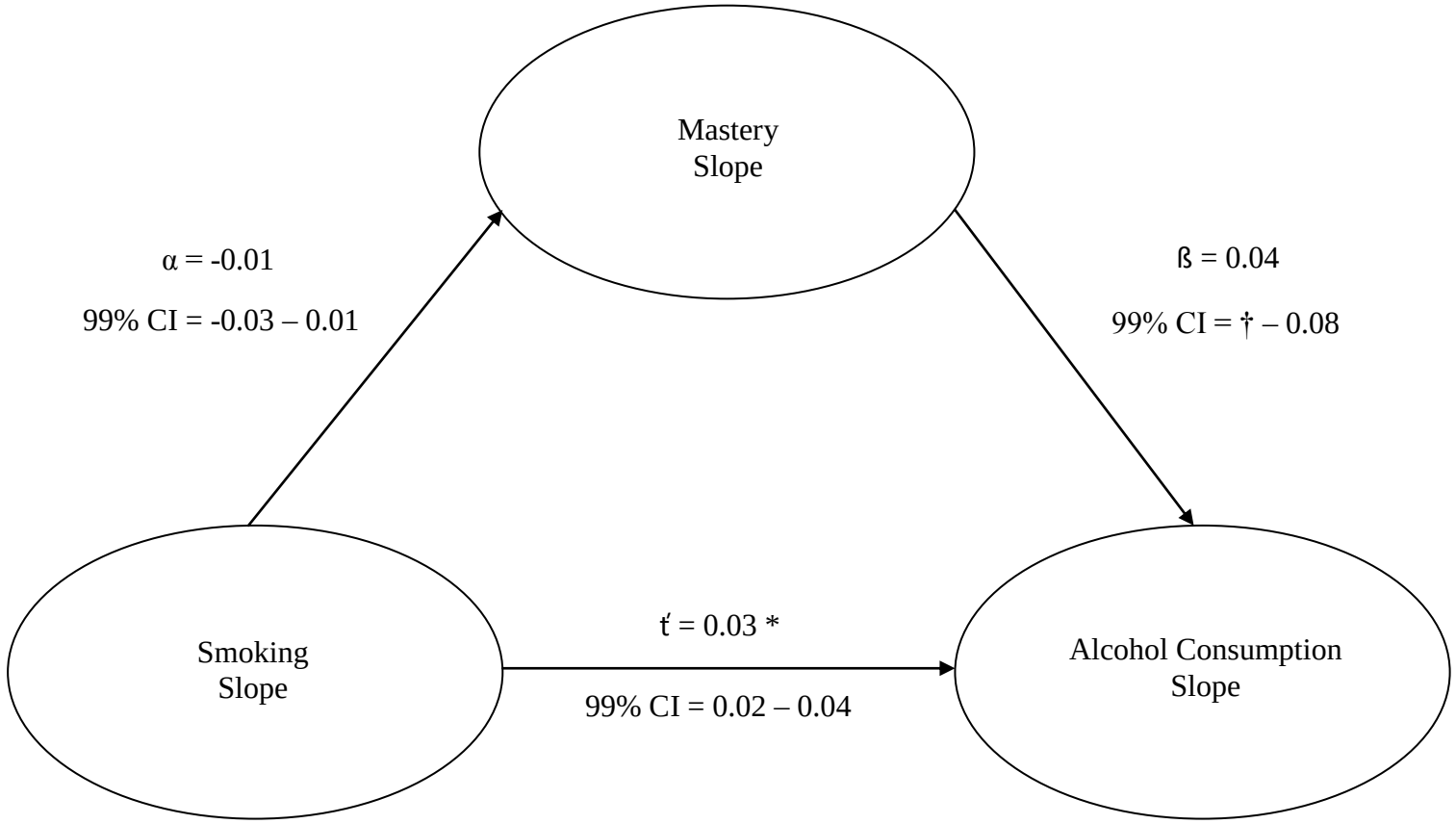


CI: Confidence Intervals.
Parameter estimates are unstandardized.
* Significant at $p \leq 0.01$.

4.9.6 Smoking and Alcohol Consumption:

The mediation model of smoking and alcohol consumption fit the longitudinal data well (Table 34); CFI = 0.97, RMSEA = 0.04 (90% CI = 0.04 – 0.04), and SRMR = 0.03. As observed in Figure 20, changes in smoking had no significant effect on changes in mastery (α = -0.01, 99% CI = -0.03 – 0.01). A lack of association was also observed between changes in mastery and changes in alcohol consumption (ß = 0.04, 99% CI = † – 0.08). The mediated effect of mastery was shown to be non-significant (αß = †, 99% CI = $-0.02 \times 10^{-1} - 0.01 \times 10^{-1}$) indicating that perceived mastery did not mediate the relationship between the slopes of smoking and alcohol consumption. The direct effect of smoking on alcohol consumption was significant (ť = 0.03, 99% CI = 0.02 – 0.04, $p < 0.01$).

Figure 20: Mediation of Mastery in the Smoking and Alcohol Consumption Model (n = 15,166)



CI: Confidence Intervals.
Parameter estimates are unstandardized.
† Confidence interval was < 0.001.
* Significant at $p \leq 0.01$.

Chapter 5
Discussion

5.1 Overview:

Although multiple health behaviour change research may represent the future of public health policies and strategies (L. Gordon, et al., 2007; J. O. Prochaska, 2008), a number of questions relating to the interrelationship of multiple behaviours continue to persist. Using a longitudinal nationally representative population-based database of Canadians, the current study attempted to address two of these concerns by assessing the following objectives: 1) to evaluate co-variation among health behaviours; specifically alcohol consumption, leisure-time physical activity, and smoking, and 2) to examine whether mastery acts as a mediating cognitive mechanism that facilitates changes between multiple health behaviours. In subsequent paragraphs, the discussion of the study results were complemented with possible explanations as to why these findings may have transpired as well as implications that these conclusions may have for future health promotion programs and strategies.

5.2 Attrition:

For years, multiple health behavioural research has acknowledged the need for longitudinal study designs in evaluating the interrelationship of behavioural change (Blakely, et al., 2004; Butterfield, et al., 2004; Costakis, et al., 1999; Garrett, et al., 2004; Klein-Geltink, et al., 2006; Pronk, Peek, et al., 2004). Compared to cross-sectional designs, longitudinal studies are more appropriate for examining behavioural changes as they are capable of evaluating behavioural trajectories over time. However, longitudinal studies are not without limitations. One of the more common limitations associated with longitudinal studies is attrition (Lilienfeld & Stolley, 1994; Statistics Canada, 2008). Attrition refers to a reduction in the original sample size which is attributed to non-response in the form of refusal, an inability to locate, incapable of being interviewed, or partial response (Statistics Canada, 2008). When attrition is introduced into a longitudinal study, there is always a concern that those individuals who remain in the study may no longer represent the population from which they were obtained (Klesges, et

al., 1999). This is known as selection bias (Janzon, Hanson, Isacsson, Lindell, & Steen, 1986; Last, 2001). When present, this bias could possibly compromise the generalizability of the research findings (Cunradi, Moore, Killoran, & Ames, 2005). Generalizability, often known as external validity, refers to the ability of research findings to present unbiased associations that are representative of the target population from which the sample was recruited (Last, 2001). To avoid this potential limitation, researchers should employ every possible method to retain study participants (Janzon, et al., 1986). Although Statistics Canada utilized a variety of approaches to improve the retention of sample participants (Statistics Canada, 2008), attrition could not be prevented throughout subsequent cycles. By the seventh cycle of the current study, 67% of Canadians had completed the NPHS survey. However, in this analysis, the proportion of Canadians who provided valid responses for each of the variables of interest was calculated at 51%. In comparison to studies of shorter duration, approximately 10 years in length, response rates of approximately 70% have been reported (Goldberg, Chastang, Zins, Niedhammer, & Leclerc, 2006; Radler & Ryff, 2010). As attrition rates are often influenced by the duration of time between initial and follow-up periods (Cunradi, et al., 2005), it is reasonable to conclude that attrition rates would likely resemble that of the current study had these studies persisted for an additional four years.

Those individuals who did not provide valid responses for each of the variables of interest were identified by specific demographic, cognitive-behavioural, behavioural, and physical health characteristics. In regards to demographic characteristics, Canadians who were younger, married or formerly married, and demonstrating higher levels of education, income adequacy, and BMI scores were more likely to exhibit a willingness to participate in the NPHS at the final assessment. The ability of demographic characteristics to predict participation at future assessment periods has been evaluated by others. In a national study, individuals who were married, better educated and reported higher BMI scores were more likely to continue to participate in additional data collection periods (Radler & Ryff, 2010). Others have also documented similar trends between attrition and education (Cunradi, et al., 2005; de Graaf, Bijl, Smit, Ravelli, & Vollebergh, 2000).

Variations in gender, age and marital status have been observed in previous research (Cunradi, et al., 2005; de Graaf, et al., 2000; Goldberg, et al., 2006). Similar to the current findings, de Graaf et al. (2000) found no association between attrition and gender. However, others have found that males (Goldberg, et al., 2006) and females (Cunradi, et al., 2005) were more likely to participate in a future follow-up. Further research is required to clarify the association between attrition and gender.

In considering age, the current analysis found that younger Canadians were more likely to participate in the seventh cycle of the NPHS. The use of a continuous rather than categorical variable could be responsible for inconsistent findings between studies. The current study had chosen to use a continuous variable to represent age, while other studies have preferred to group age into specific categories (Cunradi, et al., 2005; de Graaf, et al., 2000; Goldberg, et al., 2006). The utilization of age as a categorical variable implies that each individual within a particular category is of the same age. For example, in an 18 to 24 age grouping, no distinction is made between individuals 18 years of age and individuals who are 24 years of age. The use of a continuous variable would be a more accurate representation of an individual's actual age and may result in a different trend than what was reported when age was categorized into specific groupings. Furthermore, differences in the age range of the recruited sample may have also had a role in the inconsistent findings. For example, at baseline, Canadians aged 12 to 102 years of age were included in the current analysis. Other studies have recruited samples with more restrictive age ranges (Cunradi, et al., 2005; de Graaf, et al., 2000; Goldberg, et al., 2006). Finally, as the current sample may have included a larger proportion of older individuals, the increased likelihood of attrition among older individuals could be attributed to mortality/morbidity (de Graaf, et al., 2000).

In regards to marital status, the present study found that married individuals were more likely to participate in the seventh cycle of data collection. These results are in partial agreement with those presented by de Graaf et al. (2000) who demonstrated that the odds of failing to locate participants at a future follow-up period was reduced among those living with a partner. However, in examining additional types of attrition, de Graaf et al. reported that the likelihood of attrition as a result of refusal or morbidity/mortality was not associated with marital status. In the current study, the most common form of

attrition was non-response which entailed both refusals and individuals who could not be located (Statistics Canada, 2008). Had attrition been assessed in its different forms, failure to locate, refusal, and morbidity/mortality, similar findings as those of de Graaf et al., (2000) may have been reported. In additional studies, a higher probability of participation was observed among married men, while no such association was demonstrated among women (Goldberg, et al., 2001). Others have been unable to identify a significant association between attrition and marital status (Cunradi, et al., 2005; Goldberg, et al., 2006). Additional research is necessary to determine the association between marital status and attrition.

Of particular interest was the evaluation between participation and behavioural and physical health characteristics. There appears to be some consensus that both smoking behaviour and physical health status are associated with attrition (Cunradi, et al., 2005; Goldberg, et al., 2006; Morrison, et al., 1997). Furthermore, for leisure-time physical activity energy expenditure, the findings in the current study were in agreement with those of Radler and Ryff (2010) as vigorous exercise had no association with longitudinal retention. For alcohol consumption, the findings are more controversial. Some have shown that simply consuming alcohol is related to a reduced likelihood of participating in a follow-up survey (Morrison, et al., 1997), whereas others have suggested that more excessive amounts of alcohol consumption are related to lower participation at follow-up (Goldberg, et al., 2006) and a greater likelihood of failing to locate individuals (de Graaf, et al., 2000). Among other studies, the consumption of alcohol has shown no association with retention (Radler & Ryff, 2010), non-response (Cunradi, et al., 2005) as well as attrition due to refusal or morbidity/mortality (de Graaf, et al., 2000). It is difficult to identify why the findings involving alcohol consumption substantially vary. Again, this is an area in which future research will need to address.

From the logistic regression analysis, one could conclude that several characteristics were associated with retention. The fact that specific individuals were less likely to participate in the seventh cycle of the NPHS could have substantial implications on the external validity of the study findings (Cunradi, et al., 2005). This analysis was concerned with the effect that smoking behaviour, alcohol consumption, and the number of chronic conditions an individual possessed would present on the internal and external validity of

this study. If specific individuals had withdrawn from this analysis, the results may not be applicable to general smokers, consumers of alcohol, or individuals with chronic conditions. Furthermore, the exclusion of specific individuals may bias the calculated covariances and correlations. For example, according to the parameter estimates of the logistic regression, for every additional cigarette that an individual smoked each day, the odds of participation in the seventh cycle decreased by 1%. As a result, heavier smokers exhibited a greater likelihood of attrition. Heavier smokers often demonstrate lower levels of motivational readiness to achieve smoking cessation (DiClemente, et al., 1991; Emmons, et al., 1994), higher levels of nicotine dependence, and a greater difficulty with cravings, withdrawal symptoms and achieving cessation (Killen, Fortmann, Telch, & Newman, 1988). Thus, it is reasonable to hypothesize that those smokers who were least likely to change their smoking behaviour were no longer participating in the NPHS at the final follow-up. Had heavier smokers continued to participate in the NPHS, their inclusion may have attenuated significant concurrent behavioural changes that were observed in their absence.

The trend observed for smoking was unlike the one reported for alcohol consumption as greater quantities of alcohol consumption was associated with participating in the seventh cycle. Therefore, concurrent changes between alcohol consumption and other behaviours could be difficult to observe as individuals who consume excessive amounts of alcohol report little desire to change their alcohol consumption (Rosal, et al., 2000). However, it is conceivable that such individuals may choose to change additional health behaviours (Rosal, et al., 2000) and this could increase one's intentions on changing alcohol consumption (Unger, 1996).

The likelihood of participating in the seventh cycle decreased by 7% for each additional chronic condition that an individual possessed. However, unlike smoking, the possession of numerous chronic diseases is associated with greater motivational readiness to change unhealthy behaviours (Boyle, et al., 1998; Keenan, 2009). Thus, individuals who were more likely to achieve behavioural changes were not included in the seventh cycle of the NPHS. Had individuals who possessed multiple chronic conditions been retained at the final follow-up, non-significant associations in concurrent behavioural changes may have reached statistical significance. Whether the increased likelihood of implementing

behavioural changes among less addictive smokers would be offset by the challenge of changing behaviours among individuals who consume greater quantities of alcohol and possess fewer chronic conditions was unknown. However, all three indicators appeared to play a significant role in attrition and thus may have influenced the generalizability of the current results. Consequently, caution should be exhibited when generalizing these findings back to the broader population.

5.3 Sample Characteristics:

In the past, multiple behavioural change studies have recruited samples that have exclusively or predominantly consisted of males (Carmelli, et al., 1993; T. Gordon & Doyle, 1986; Nagaya, et al., 2007), females (McDermott, et al., 2004; Perkins, et al., 1993; Saules, et al., 2004), adolescences (Audrain-McGovern, et al., 2003; Terry-McElrath & O'Malley, 2011), specific age groups (Breslau, et al., 1996; Carmelli, et al., 1993; Perkins, et al., 1993), ever smokers (Boudreaux, et al., 2003), individuals possessing a chronic condition (Boudreaux, et al., 2003; Boyle, et al., 1998), university students (Keller, et al., 2008), smokers (Kahler, et al., 2009), as well as pregnant women (Pirie, et al., 2000). This study attempted to resolve this limitation by incorporating a large nationally representative sample of Canadians. In 1994/1995, the current sample was comprised almost equally between males and females with an average age of 41 years. The majority of Canadians were married or cohabitating with a partner. Over subsequent cycles of data collection, the proportion of married or cohabitating Canadians increased resulting in a decrease in the percentage of single individuals. In regards to education, over half of the initial sample had acquired at least some post-secondary school. By the seventh cycle, this proportion of individuals had increased by nearly 20%. This increasing trend in higher levels of education has been observed by others (Steffen, et al., 2006). For income adequacy, Canadian households appeared to be earning greater incomes over subsequent cycles. However, this trend could be misleading as the percentage of Canadians who were unwilling to response to this particular question increased from 5.0 to 44.6% over the duration of the NPHS. In 1994/1995, the average BMI was 24.8 kg/m^2 suggesting that the average Canadian was under weight or normal weight. However, over time, BMI increased to 26.6 kg/m^2 confirming that the majority

of individuals were overweight or obese. These findings were not surprising as others have reported an increasing trend in weight gain and BMI scores with the passage of time (D. E. King, Mainous, Carnemolla, & Everett, 2009; Mozaffarian, Hao, Rimm, Willett, & Hu, 2011; Orpana, Tremblay, & Fines, 2007; Steffen, et al., 2006).

5.4 Prevalence of Multiple Health Behaviours:

The majority of research pertaining to health behaviours has typically evaluated single health behaviours as opposed to multiple health behaviours (Klein-Geltink, et al., 2006; Nigg & Long, 2012). Determining the prevalence of multiple unhealthy behaviours would be beneficial for public health professionals and health promotion programs in understanding the incidence, prevention, screening, and treatment of chronic diseases (Pronk, Anderson, et al., 2004). The recognition of trends in multiple unhealthy behaviours would also provide evidence of the success of innovative policies and programs (Hale & Viner, 2012).

Previous literature has determined that 39 to 80% of the general population possess multiple unhealthy behaviours or risk factors. Such behaviours/risk factors may include physical inactivity, smoking, excessive alcohol consumption, unhealthy dietary intake, or overweight/obesity (Berrigan, et al., 2003; Fine, et al., 2004; Klein-Geltink, et al., 2006; Rosal, et al., 2001). The findings from Table 15 indicate that the engagement of multiple unhealthy behaviours ranges from 21.5 to 26.9% in this sample of Canadians. At first glance, this would suggest that these findings greatly underestimate the prevalence of multiple unhealthy behaviours. However, there are two explanations that may provide justification for the lower prevalence of multiple unhealthy behaviours observed in this study. The utilization of diverse criteria to characterize health behaviours could be one possibility. This is perhaps most evident in the evaluation of smoking status. Although the classification of smoking status would seem to be relatively straightforward, various criteria have been suggested to characterize smokers including current tobacco use (Poortinga, 2007b; Rosal, et al., 2001), current daily tobacco use (Klein-Geltink, et al., 2006), daily or occasional tobacco use (Coups, et al., 2004; Fine, et al., 2004) or whether individuals had smoked a minimum of 100 cigarettes in their lifetime and were currently smoking tobacco products (Pronk, Anderson, et al., 2004). Variations in the criteria for

alcohol consumption and physical inactivity appear to be just as common. While some have often relied upon daily or weekly cut-offs to distinguish between excessive levels of alcohol consumption (Klein-Geltink, et al., 2006; Poortinga, 2007b; Rosal, et al., 2001), others have incorporated a measure of binge drinking as an adjunct to daily or weekly alcohol consumption cut-offs (Berrigan, et al., 2003; Coups, et al., 2004; Fine, et al., 2004; Pronk, Anderson, et al., 2004). Furthermore, while this study assessed physical inactivity in regards to leisure-time energy expenditure, others have shown a tendency to measure physical inactivity by assessing a lack of adherence to specific frequency and duration guidelines (Coups, et al., 2004; Fine, et al., 2004; Poortinga, 2007b; Pronk, Anderson, et al., 2004; Rosal, et al., 2001). In this study, the criteria utilized to distinguish healthy from unhealthy behaviours were based upon Canadian guidelines for alcohol consumption (Bondy, et al., 1999; Wilkins, 2002) and leisure-time physical activity energy expenditure (Katzmarzyk & Tremblay, 2007; Stephens, et al., 1986). With the exception of Klein-Geltink et al. (2006), the majority of the aforementioned studies have incorporated American recommendations for health behaviours. Until health professionals can agree upon recommended guidelines for healthy behaviours, it is expected that prevalence rates will continue to vary between studies.

The lower prevalence rates of multiple unhealthy behaviours reported in the current study could also be attributed to the exclusion of dietary habits. Unlike previous studies (Berrigan, et al., 2003; Poortinga, 2007b; Pronk, Anderson, et al., 2004; Rosal, et al., 2001), this study does not take into consideration dietary habits as information pertaining to fruit and vegetable consumption was limited to only a few cycles in the NPHS. Furthermore, data pertaining to dietary fat intake was non-existent. Had dietary habits been included in some capacity, either fruit and vegetable consumption and/or saturated fat intake, the prevalence rates of multiple unhealthy behaviours would have surely increased. For example, smokers and physically inactive individuals are known to consume high fat diets (Rosal, et al., 2001). Therefore, these individuals would no longer possess one unhealthy behaviour, either smoking or leisure–time physical inactivity, but rather multiple unhealthy behaviours; unhealthy diet and smoking or unhealthy diet and leisure-time physical inactivity.

The addition of dietary habits would also reduce the prevalence rates of specific behavioural combinations. For instance, the behavioural combination of physical inactivity and smoking demonstrates an initial prevalence rate of 21.5%. However, this behavioural combination includes both individuals with and without adequate dietary habits. The evaluation of individuals with unhealthy dietary habits would create an additional behavioural category; physical inactivity, smoking, and unhealthy diet. This new category would remove individuals from the physical inactivity and smoking category and consequently decrease the prevalence rate of Canadians who were strictly physically inactive smokers.

Similar to dietary intake, prevalence rates of multiple unhealthy behaviours have often included BMI estimates (Coups, et al., 2004; Fine, et al., 2004; Klein-Geltink, et al., 2006; Pronk, Anderson, et al., 2004). However, obesity is a product of both physical inactivity and/or unhealthy dietary habits as opposed to an actual health behaviour. Therefore, obesity was not included in the prevalence rates of multiple health behaviours.

Although several inconsistencies exist in the prevalence rates of single and multiple health behaviours, a number of similarities were observed. As in other studies, physical inactivity was the most common unhealthy behaviour reported in this study (Coups, et al., 2004; Fine, et al., 2004; Klein-Geltink, et al., 2006; Pronk, Anderson, et al., 2004). The proportion of excessive consumers of alcohol and current daily smokers was similar to that of Canadian and American adult samples (Coups, et al., 2004; Klein-Geltink, et al., 2006; Rosal, et al., 2001). Furthermore, the percentage of Canadians who exclusively consumed excessive amounts of alcohol or were strictly smokers was similar to the prevalence rates reported by Klein-Geltink et al. (2006). In regards to multiple health behaviours, other studies have demonstrated prevalence rates of 4% for excessive alcohol consumption and physical inactivity (Rosal, et al., 2001), 13% for physical inactivity and smoking (Rosal, et al., 2001), and 1 to 2% for excessive alcohol consumption and smoking (Klein-Geltink, et al., 2006; Rosal, et al., 2001). In addition, our prevalence estimates for the simultaneous inclusion of all three unhealthy behaviours resembled that of Klein-Geltink et al., (2006), while the proportion of Canadians meeting the recommendations for all three behaviours was similar to that reported by Fine et al. (2004).

Perhaps the most favourable changes were among those Canadians who were initially physically inactive and smoking. The proportion of physically inactive smokers steadily declined from a high of 21.5% in 1994/1995 to a low of 14.2% in 2006/2007. This decrease in physically inactive smokers is not surprising considering that both cross-sectional and longitudinal studies have documented that physical activity is associated with smoking cessation (W. K. deRuiter, et al., 2008; Gauthier, et al., 2012; Nagaya, et al., 2007; Perkins, et al., 1993; Wen, Wai, Tsai, & Yang, 2012). Social unacceptability could also be responsible for the decreasing prevalence of smoking. Furthermore, it is also possible smokers encounter stricter legislation as well as more effective and accessible resources and professional assistance. While one cannot discount that positive behavioural changes in physical activity and smoking had some influence on the decreasing trend of physically inactive smokers, another likely explanation would be attrition. As smokers became unwilling or unable to continue to participate in the NPHS, they were no longer included in the calculated prevalence rates of multiple behavioural combinations. Therefore, the declining trend in the proportion of Canadians who were physically inactive and smoking could be attributed to a lack of participation. The percentage of individuals who met the recommended guidelines for all three health behaviours, alcohol consumption, physical activity, and smoking behaviour, also demonstrated a positive trend particularly from 2000/2001 (13.3%) to 2006/2007 (19.7%). However, once again, this increasing trend could be attributed to a reduction in physically active smokers and/or attrition.

Interestingly, rates of multiple health behaviours that included alcohol consumption appeared to increase across the seven cycles of the NPHS. Once again, one should not overlook the role that attrition may have had on this increasing trend in alcohol consumption. On the other hand, it is conceivable that alcohol consumption is considered socially acceptable by the general population, particularly in comparison to tobacco use.

The evaluation of multiple health behaviour patterns provides a better understanding of the risk associated with chronic diseases (Klein-Geltink, et al., 2006). As individuals maintain multiple unhealthy behaviours, they will continue to exhibit an increased risk of mortality from cancer, coronary heart disease, and stroke (Chang, et al., 2001; Knoops, et al., 2004; Meng, et al., 1999). The current findings demonstrate that from 1994/1995 to

2006/2007, specific behavioural combinations had significantly improved while other combinations demonstrated negative trends. Once unhealthy behavioural patterns are recognized, public health professionals can begin to design and implement strategies that not only meet the specific needs of individuals, but result in the adoption and maintenance of favourable behavioural changes that reduce the risk of chronic diseases.

5.5 Single Health Behaviour Change:

In this observational study, unconditional growth curve findings suggest that Canadians demonstrated the capability to adopt and/or maintain significant beneficial behavioural changes as individuals reported an increase of 0.04 kcal/kg/day in leisure-time physical activity energy expenditure. While this longitudinal trajectory was comparable to previously reported trends for total leisure-time physical activity (Jacobs, et al., 1991; Steffen, et al., 2006), high-intensity leisure-time physical activity (Jacobs, et al., 1991; Steffen, et al., 2006; Talbot, Fleg, & Metter, 2003), and physical activity energy expenditure (Craig, et al., 2004; I. M. Lee, et al., 1992), there a consensus in the scientific community that physical activity typically declines with chronological age. This positive behavioural trajectory for leisure-time physical activity could be attributed to the heterogeneity of the sample, specifically the substantially large range in age at the first cycle.

The resurgence of population based physical activity programs such as ParticipAction have utilized mass media campaigns to increase awareness and interest in adopting physical activity among the Canadian general population (Craig, Bauman, Gauvin, Robertson, & Murumets, 2009; Plotnikoff, et al., 2009). Canada on the Move, another population based program, has also promoted physical activity participation in the form of daily walking (Craig, Tudor-Locke, & Bauman, 2007). In addition to population initiatives, an environment that is conducive in supporting physical activity participation is also critical. The development of accessible sidewalks, parks, playgrounds, and sport opportunities within communities may provide such support and encouragement (Carson, Kuhle, Spence, & Veugelers, 2010).

A favourable change in smoking behaviour was also observed as a reduction of 0.32 cigarettes/day at each biennial cycle was reported among Canadians. This decreasing

trend in tobacco use has been observed by others (Centers for Disease Control and Prevention, 2012; Filion, et al., 2012; Le Faou, Baha, Rodon, Lagrue, & Menard, 2009; McDermott, et al., 2008; Shields, 2007a; Waller, Cohen, Ferrence, Bull, & Adlaf, 2003). Government legislation and pharmacological treatment are primarily responsible for the reported decrease in daily tobacco use (Irvin & Brandon, 2000). Over the years, legislation has played a critical role in tobacco control. Smoking restrictions, in the home, public places, and the workplace, are increasing in popularity and appear to be an effective strategy in decreasing daily cigarette use as well as enhancing motivational readiness for achieving smoking cessation (Shields, 2007a, 2007b). Higher cigarette prices may also contribute to a reduction in daily cigarette use (Farrelly, Nimsch, Hyland, & Cummings, 2004) as youth smoking is often susceptible to fluctuations in cigarette costs (Kostova, Ross, Blecher, & Markowitz, 2011). Finally, one should not overlook the critical role that nicotine replacement therapy has had in decreasing smoking rates (Stead, Perera, Bullen, Mant, & Lancaster, 2008). As daily cigarette use continues to decrease through legislation and pharmacological agents, the odds of achieving smoking cessation is enhanced (Hymowitz, et al., 1997) and consequently health benefits should become apparent.

Unfortunately, not all behavioural changes exhibited a favourable longitudinal trend as alcohol consumption increased biennially by 0.03 beverages/day. In recent years, both the prevalence of individuals consuming moderate or excessive quantities of alcohol (D. E. King, et al., 2009; Li, et al., 2009) and the average consumption of alcohol has increased (Mays, Depadilla, Thompson, Kushner, & Windle, 2010). However, compared to other health behaviours, alcohol consumption is unusual as small quantities of alcohol appear to be beneficial to one's health, whereas excessive amounts result in adverse consequences (Knoops, et al., 2004; Ronksley, et al., 2011). Subsequently, the increasing trend in alcohol consumption could be attributed to the prevention of cardiovascular disease. Since the majority of the general population continues to acknowledge the health benefits associated with moderate alcohol consumption (Ogborne & Smart, 2001), the initiation of this behaviour could become more appealing and acceptable. Similar to smoking, social norms may have a prominent role in the consumption of alcohol. The perception that others partake in the consumption of alcoholic beverages can result in a

greater likelihood of actual use (Arbour-Nicitopoulos, Kwan, Lowe, Taman, & Faulkner, 2010) as well as the consumption of higher quantities of alcohol (Haug, Ulbricht, Hanke, Meyer, & John, 2011; O'Grady, Cullum, Tennen, & Armeli, 2011).

Demographic characteristics may play a central role in the behavioural change process. As individuals age, they demonstrate a greater likelihood of adhering to multiple healthy behaviours (Berrigan, et al., 2003; Fine, et al., 2004; Pronk, Anderson, et al., 2004; Ramage-Morin, Shields, & Martel, 2010). On average, it is not until age 53 that individuals typically meet the recommended guidelines for alcohol consumption, physical activity, tobacco use, and diet (Berrigan, et al., 2003). Over time, one becomes more aware of the health implications associated with unhealthy behaviours. Thus, improvements in health behaviours could be attributed to education (Boniface, et al., 2001; Pronk, Anderson, et al., 2004). Susceptibility to chronic diseases often increases with age. Perhaps by adopting a healthier lifestyle, one may believe they can prevent or delay the occurrence of debilitating conditions. The influence of age, education, and additional demographic characteristics on behavioural changes will be discussed in further detail in subsequent sections.

Although each of these three behavioural trajectories had reached statistical significance, one could argue that the estimated magnitude of such behavioural changes were quite small. However, small and attainable behavioural changes at the population level can have considerable effects on morbidity, mortality, and health care costs (Atkins & Clancy, 2004; Guttman, Kegler, & McLeroy, 1996; Lean, Lara, & Hill, 2006; Rose, 1985). For example, if the prevalence of Canadians who participated in sufficient levels of physical activity were to increase by 10%, a savings of $150 million per year would be incurred by the Canadian health care system (Katzmarzyk, et al., 2000). In the case of alcohol, a slight decline in consumption during a 20 year period had been associated with substantial reductions in morbidity and mortality rates (Smart & Mann, 1987). While the behavioural changes observed in the current analysis were small, it is important to consider that these changes most likely occurred without the assistance of public health interventions. It is expected that more substantial behavioural changes could be acquired through the support of public health interventions (Emmons, Shadel, et al., 1999). Although one must acknowledge the cost associated with developing and implementing

such interventions, only a small reduction in unhealthy behaviours, 1.0 to 1.5%, would be necessary to offset the cost of these health promotion programs (Ozminkowski, et al., 2004).

Aside from the behavioural trajectories, each of the three unconditional growth curve models revealed a significant negative covariance between their respective intercept and slope. In the case of alcohol consumption, the negative covariance suggested that Canadians who reported high levels of alcohol consumption in 1994/1995 demonstrated slower rates of positive growth over time. On the other hand, those Canadians who demonstrated lower levels of alcohol consumption in 1994/1995 were shown to increase their consumption at a faster rate over subsequent cycles. A significant negative correlation between the intercept and slope of alcohol consumption has been previously reported (Curran, et al., 1997; Mays, et al., 2010). The negative intercept-slope covariance for leisure-time physical activity had a similar interpretation as that of alcohol consumption. For smoking, the negative covariance implied that Canadians who initially smoked greater quantities of cigarettes would demonstrate a steeper decline in their smoking behaviour. These findings are in agreement with previous research (Friend & Pagano, 2005; Garcia, Fernandez, Schiaffino, Peris, & Borras, 2005; Joseph, Bliss, Zhao, & Lando, 2005; McDermott, et al., 2008). There are two possible explanations that may account for the observed negative intercept-slope covariances. First, known as regression to the mean, individuals may initially report an extreme value, but state values that are considered "normal" on subsequent assessments (Davis, 1976). These 'normal' values would suggest that growth was occurring at a slower rate when in actuality this would not be the case. Second, it is likely that a ceiling effect was present for alcohol consumption and leisure-time physical activity energy expenditure. In other words, individuals with initially high levels of a particular behaviour have little opportunity to achieve additional improvements compared to their counterparts who reported lower initial values. Others have also suggested the existence of a ceiling effect among health behavioural changes (Emmons, Linnan, Shadel, Marcus, & Abrams, 1999). Unlike alcohol consumption and leisure-time physical activity energy expenditure, smoking behaviour did not demonstrate a ceiling effect, but rather a floor effect. Thus, Canadians with lower initial values

exhibited little opportunity to incur further reductions in smoking compared to Canadians who demonstrated higher levels of tobacco use.

Over the last 12 years, it is reasonable to believe that favourable changes in health behaviours would have a significant reduction on the occurrence of chronic conditions in Canada. However, as observed in the current study as well as by others (Deering, Lix, Bruce, & Young, 2009; D. S. Lee, et al., 2009), chronic conditions among Canadians appear to be on the rise. The increasing trajectory of alcohol consumption could be partially responsible. Undoubtedly, an unhealthy diet as well as obesity would also have a critical role in escalating the prevalence of chronic conditions (Deering, et al., 2009; Knoops, et al., 2004). Furthermore, it important to consider that although favourable changes were observed for leisure-time physical activity and smoking, the majority of the Canadian population continue to be physically inactive while a modest proportion of the general population partakes in tobacco use.

5.6 Multiple Health Behaviours:

To evaluate the interrelationship of multiple health behaviours, three parallel process latent growth curve models were developed: alcohol consumption and leisure-time physical activity energy expenditure, leisure-time physical activity energy expenditure and smoking, and alcohol consumption and smoking. Cross-behavioural findings of each parallel process model are discussed in subsequent paragraphs.

5.6.1 Alcohol Consumption and Leisure-Time Physical Activity Energy Expenditure:

The positive intercept-intercept covariance between alcohol consumption and leisure-time physical activity energy expenditure suggested that Canadians who reported a high level of physical activity in 1994/1995 also consumed elevated quantities of alcohol consumption in 1994/1995. Conversely, Canadians participating in lower levels of physical activity also consumed lower quantities of alcohol or practiced abstinence. This positive relationship between physical activity and alcohol consumption has been previously observed by others (M. T. French, Popovici, & Maclean, 2009; Poortinga, 2007a; Tao, et al., 2007; Terry-McElrath & O'Malley, 2011; Westerterp, Meijer, Goris, &

Kester, 2004) and could be attributed to membership in sports or exercise programs (Poortinga, 2007a). Participating in leisure-time physical activity not only provides a chance to enhance one's physical health, but also the opportunity to interact and develop social relationships with teammates or colleagues. Once established, such friendships may enhance exercise adherence (Unger & Johnson, 1995) and subsequently strengthen social relationships as individuals continue to socialize with colleagues outside of exercise facilities (Unger & Johnson, 1995). It is conceivable that interacting with friends after the completion of an exercise session may occur while consuming alcoholic beverages (M. T. French, et al., 2009).

In 1994/1995, alcohol consumption appeared to have no significant association with the rate of change in leisure-time physical activity energy expenditure. However, this was not the case for the covariance between initial levels of physical activity and future consumption of alcohol. This weak, but significant, cross-behavioural covariance suggested that Canadians with initially higher levels of energy expenditure during leisure-time physical activity also reported significantly steeper positive trajectories of alcohol consumption over subsequent years. Conversely, Canadians who demonstrated lower levels of leisure-time physical activity also reported a flatter increase in their alcohol consumption. Previous prospective epidemiological research has confirmed that higher levels of physical activity at baseline are related to the adoption or an increase of alcohol consumption (Aaron, et al., 1995; Wichstrom & Wichstrom, 2009).

The slope-slope covariance between leisure-time physical activity and alcohol consumption implied that steeper increases in physical activity were related to greater increases in alcohol consumption. On the other hand, as Canadians reported flatter increases in their leisure-time physical activity, a shallower positive trajectory in the consumption of alcohol would ensue. Unfortunately, this covariance did not reach statistical significance. These findings coincide with others who have also been unable to observe a significant association in concurrent changes between both behaviours (Laaksonen, et al., 2002; Terry-McElrath & O'Malley, 2011). While it has been suggested that promoting and integrating physical activity into alcohol treatment programs could produce beneficial changes in alcohol consumption (Sinyor, et al., 1982), the current findings implied that improving one's leisure-time physical activity may not

translate into changes in alcohol consumption. Perhaps an observational study was insufficient in producing similar behavioural changes that would occur during the course of an intervention. Despite the lack of association in behavioural changes between alcohol consumption and physical activity, the incorporation of physical activity as an adjunct to alcohol treatment may provide alternative benefits. Individuals participating in such programs often possess the capability and express an interest in physical activity (Read, et al., 2001; Sinyor, et al., 1982) as well as experience a reduction in the urge to consume alcohol (Ussher, et al., 2004).

5.6.2 Leisure-Time Physical Activity Energy Expenditure and Smoking:

The negative cross-behavioural intercept-intercept covariance indicated that, initially, Canadians who reported high levels of leisure-time physical activity energy expenditure also exhibited a lower daily quantity of cigarette use which may have included complete abstinence. On the other hand, Canadians who demonstrated lower levels of physical activity also smoked a greater number of cigarettes each day. These findings were not surprising as smokers often demonstrate poor adherence to physical activity programs (Cooper, et al., 2007) and thus report less physical activity compared to their non-smoking counterparts (Barrett, Anda, Croft, Serdula, & Lane, 1995; Campbell, et al., 2000; Cooper, et al., 2007; Larson, Story, Perry, Neumark-Sztainer, & Hannan, 2007; Pate, Heath, Dowda, & Trost, 1996; Terry-McElrath & O'Malley, 2011; Wichstrom & Wichstrom, 2009). It has been suggested that physical activity programs may need to be specifically structured and tailored to meet the needs of current smokers (Cooper, et al., 2007). Naturally, interventions developed for those individuals who are currently taking action to change an unhealthy behaviour would be ineffective for individuals who have no intention of changing their behaviour (Nigg, et al., 1999). Smokers may require additional focus, motivation, and encouragement to improve adherence rates and consequently physical activity levels (Cooper, et al., 2007).

A significant positive covariance was observed between the intercept of physical activity and the slope of smoking. This suggested that Canadians who participated in high levels of physical activity in 1994/1995 demonstrated a shallower decrease in daily cigarette use. Alternatively, those individuals who initially expended lower levels of energy

during leisure-time physical activity exhibited a greater decline in tobacco use over subsequent cycles. The positive covariance between these two latent variables was unexpected as it was believed that Canadians with higher initial levels of physical activity would report steeper declines in tobacco use. However, others have also reported a similar association (Wichstrom & Wichstrom, 2009). Once again, this covariance could be attributed to a floor effect. Compared to physically active smokers, physically inactive Canadians reported significantly greater levels of tobacco use. Consequently, physically inactive smokers could reduce their cigarette use at a faster or steeper rate compared to physically active smokers.

The positive covariance between the intercept of smoking and the slope of physical activity did not reach statistical significance. Therefore, initial smoking status was not related to changes in leisure-time physical activity energy expenditure. Coinciding with the present results, Cooper et al. (2007) found that initial smoking behaviour was not associated with changes in physical activity suggesting that tobacco use does not hinder or prevent improvements in physical activity levels.

As a final point, a significant negative slope-slope covariance was found between leisure-time physical activity energy expenditure and tobacco use. Therefore, an increasing positive trajectory in physical activity energy expenditure corresponded to a steeper decline in smoking behaviour. Alternatively, a flatter positive trend in physical activity coincided with a shallower negative trend in tobacco use. In previous studies, behavioural intentions to change physical activity and smoking were not significantly associated with one another (Boudreaux, et al., 2003). However, behavioural intentions do not always translate into actual behaviour change (Callaghan, et al., 2007). The current findings confirm that changes in these two health behaviours are interrelated (Laaksonen, et al., 2002; Nagaya, et al., 2007; Terry-McElrath & O'Malley, 2011). However, it is important to acknowledge that the observed slope-slope correlation was weak ($r = -0.11$).

Unfortunately, causality was not a focal point in the current analysis. Furthermore, it would be impractical to establish such a relationship as covariances and correlations are not indicative of cause and effect associations (H. Frank & Althoen, 1994; Kitchens, 1998). Therefore it was difficult to determine which behavioural change, physical

activity or smoking, should be initially implemented. Establishing causality in the interrelationship between physical activity energy expenditure and smoking would be an area of research that should be addressed in the future as a consensus has yet to be reached (Audrain-McGovern, et al., 2003; Costakis, et al., 1999; Nagaya, et al., 2007).

The development of innovative strategies, policies, and public health programs that educate, prevent, and assist younger and more dependent smokers to achieve smoking cessation are necessary (P. I. Frank, et al., 2004). Physical activity may provide such an opportunity. In recent years, consideration has been given to physical activity as a potential tobacco harm reduction strategy (W. deRuiter & Faulkner, 2006; W. K. deRuiter, et al., 2008; Everson, Taylor, & Ussher, 2010; Weinstein, Marcus, & Moser, 2005). Physical activity has shown the ability to diminish the urge to smoke (Daniel, Cropley, & Fife-Schaw, 2007; A. H. Taylor, Katomeri, & Ussher, 2005), minimize withdrawal symptoms (Daniel, et al., 2007), reduce the number of cigarettes smoked on a daily basis (W. K. deRuiter, et al., 2008), improve the likelihood of attempting cessation (W. K. deRuiter, et al., 2008; Gauthier, et al., 2012), lower the risk of mortality from ischemic heart disease and stroke (Wen, et al., 2012), and enhance the quality of life among smokers (Ferrucci, et al., 1999). Furthermore, smokers have reported a tendency to possess a greater number of unhealthy behaviours suggesting that smoking facilitates the adoption of additional unhealthy behaviours (Campbell, et al., 2000; Emmons, Linnan, et al., 1999; Emmons, et al., 1994; Keller, et al., 2008; Prattala, et al., 1994; Rosal, et al., 2001). Health professionals may have more success in changing one's smoking behaviour if they initially target other health behaviours such as physical activity (Butterfield, et al., 2004). Initially, focusing on physical activity would be a reasonable choice as smokers express a greater interest in changing their physical activity levels as opposed to achieving smoking cessation (Campbell, et al., 2000; Garrett, et al., 2004). As a successful change in physical activity is adopted and maintained, additional favourable behavioural changes including smoking cessation may ensue (Audrain-McGovern, et al., 2003; Costakis, et al., 1999; Finnegan & Suler, 1985; Sherwood, et al., 2000).

A transfer effect refers to the acquisition of knowledge, competence, and skills during the adoption of one behaviour which is later conveyed towards additional behaviours (S. M.

Barnett & Ceci, 2002). This transfer effect may also provide justification for the observed co-variation between physical activity and smoking. Evidence of a transfer effect between physical activity and smoking has been presented suggesting that regular physical activity is associated with a reduction in smoking behaviour (Nigg, Lee, Hubbard, & Min-Sun, 2009). Therefore, promoting physical activity may discourage one from adopting smoking behaviour as physically active individuals could be more health conscious and aware of the health consequences linked with tobacco use (Nigg, et al., 2009).

Although physical activity has the potential to act as a gateway behaviour for smoking cessation, one cannot discount the possibility that smoking cessation facilitates changes in physical activity (Nagaya, et al., 2007). Weight gain is often acknowledged as a barrier in achieving smoking cessation (Milligan, et al., 1997). Individuals may choose to adopt physical activity as an effective means of weight management while attempting to change their smoking behaviour. Physical activity has demonstrated short-term success in delaying weight gain following smoking cessation (Marcus, et al., 1999). Furthermore, in an attempt to become more health conscious, individuals who achieve smoking cessation may decide to adopt additional healthy behaviours including an active lifestyle (Finnegan & Suler, 1985; Nagaya, et al., 2007).

As physical activity and smoking demonstrated a significant interrelationship with one another, it is reasonable to believe that public health programs that incorporate both behaviours could have a substantial impact on the health and well-being of smokers compared to programs which focus exclusively on smoking cessation. However, if such programs are to be implemented, health professionals will need to dedicate more time in advising and promoting physical activity as a smoking cessation strategy (Everson, et al., 2010). Naturally these multiple health behaviour programs would need to be tailored to address the specific needs and concerns of smokers. Poor adherence towards physical activity would certainly be one concern that health professionals would need to consider (Cooper, et al., 2007; Marcus, et al., 1999). Perhaps adherence rates could be enhanced by promoting leisure-time activities that are popular among smokers including walking, gardening, ice skating, and jogging (Gauthier, et al., 2012). Other concerns may include the recruitment of sedentary smokers, achieving cessation rather than harm reduction, and

maintaining favourable behavioural changes once such programs have concluded. The integration of both behaviors into a single program is not without its challenges. However, if successful, such programs could provide smokers with an innovative and effective strategy for achieving smoking cessation and living a healthier lifestyle.

5.6.3 Alcohol Consumption and Smoking:

A significant positive intercept-intercept covariance was observed between alcohol consumption and smoking. This suggested that in 1994/1995, Canadians who smoked a greater number of cigarettes on a daily basis also consumed higher quantities of alcohol. On the other hand, Canadians who were non-smokers or smoked a fewer number of cigarettes also exhibited abstinence from alcohol or consumed smaller quantities of alcohol. This covariance was expected as smoking usually occurs in conjunction with alcohol consumption. Smokers often consume greater volumes of alcohol as well as consume alcohol more frequently compared to former or non-smokers (Breslau, et al., 1996; Carmelli, et al., 1993; S. A. French, Hennrikus, & Jeffery, 1996; Perkins, et al., 1993; Torabi, et al., 1993). In addition, individuals who consume higher quantities of alcohol typically smoke more cigarettes compared to their counterparts who consume alcohol in moderation or practice abstinence (Burling & Ziff, 1988; T. Gordon & Doyle, 1986).

A significant negative covariance was found between the intercept of alcohol consumption and the rate of change in smoking. Therefore, Canadians who initially consumed higher quantities of alcohol demonstrated a steeper decline in tobacco use. This finding was unanticipated as intuition would have one believe that lower initial levels of alcohol consumption would be associated with a greater decline in cigarette use. Nevertheless, a positive relationship between the consumption of low to moderate levels of alcohol and smoking cessation has been verified by previous research (Breitling, Muller, Raum, Rothenbacher, & Brenner, 2010). Furthermore, in this sample, excessive consumers of alcohol also smoked significantly greater quantities of cigarettes. Thus, it is likely that these individuals could reduce their tobacco use at a steeper rate compared to their counterparts who consumed lower levels of alcohol and smoked fewer cigarettes per day.

The non-significant intercept-slope covariance between smoking and alcohol consumption indicated that baseline smoking status had no influence on changes in alcohol consumption over time. This negative covariance contrasts with the findings of Laaksonen et al. (2002). However, the utilization of dichotomous health behaviours and a logistic regression analysis was unlike the methodology and statistical analysis employed in the current study. Therefore, it is not surprising that differences in results occurred between the two studies.

The positive relationship between the slopes of alcohol consumption and smoking behaviour suggested that increases in the consumption of alcohol were associated with a slower decline in smoking behaviour, while a decrease in the positive trajectory of alcohol consumption corresponded to a further reduction in smoking behaviour. The fact that changes in one health behaviour influenced changes in the other behaviour coincides with the findings of cross-sectional (Keller, et al., 2008) and longitudinal research (Breslau, et al., 1996; Dierker, et al., 2006; Shaw, et al., 2011). Unfortunately, the current findings were in contrast with those of Carmelli et al. (1993) such that individuals who achieved smoking cessation may report an increase, albeit small, in their levels of alcohol consumption compared to their non-smoking counterparts. However, as former smokers reported a smaller increase in alcohol consumption compared to continuing smokers, the findings may suggest that positive changes in smoking can result in beneficial changes in alcohol consumption that would otherwise not be experienced by those individuals who were persistent smokers (Carmelli, et al., 1993). Laaksonen et al. (2002) was also unable to report a significant association in behavioural changes between smoking and alcohol consumption. However, as previously mentioned, methodological and statistical inconsistencies between this study and that conducted by Laaksonen et al. (2002) could be responsible for these conflicting results.

The positive correlation between alcohol consumption and smoking could be attributed to specific cues. The urge to participate in both behaviours demonstrates a positive association (Gulliver, et al., 1995). As these behaviours share several prompts, exposure to an unhealthy behaviour may act as a gateway that leads to the participation in an additional risky health behaviour (Miller, et al., 1983; Sobell, Sobell, Kozlowski, & Toneatto, 1990). In this case, it is believed that alcohol consumption may induce or

promote smoking related cues (Epstein, Sher, Young, & King, 2007; Field, Mogg, & Bradley, 2005; Sayette, Martin, Wertz, Perrott, & Peters, 2005) as tobacco products are often desired when consuming excessive quantities of alcohol in an attempt to enhance the effects of alcoholic beverages (Epstein, et al., 2007). Furthermore, smokers will use tobacco products several times throughout the day without succumbing to alcohol consumption (Kahler, et al., 2009). However, others have suggested that individuals who achieve smoking cessation may acquire specific cognitive behavioural techniques as well as coping strategies which assist in the ability to quit drinking (Burling & Ziff, 1988). Therefore, it appears that reducing or eliminating social, behavioural, or environmental cues may assist in initiating the adoption of healthier alcohol and smoking behaviours (Ellingstad, et al., 1999; Epstein, et al., 2007). This transfer effect between alcohol consumption and smoking as been observed by others (Nigg, et al., 2009). As these two behaviours appear to share similar characteristics, it not surprising that a stronger correlation was observed between alcohol consumption and smoking as opposed to leisure-time physical activity and smoking.

Again, causality could not be established through the use of covariances and correlations. A randomized study design would be more appropriate for establishing causality than observational data. However, if the sequence in which behavioural changes are administered is irrelevant, treatment programs which focus on changing both behaviours may become more effective by adopting a choice-based approach (Berg, et al., 2012; Campbell, et al., 2002). Permitting individuals to choose and prioritize behavioural changes to adopt and successfully maintain could provide the motivation, incentive, and self-efficacy to change additional behaviours that are more challenging and influential to their overall health and well-being (Strecher, et al., 2002). However, as previous research has contrasting opinions as to which behavioural change should be initially administered (Breslau, et al., 1996), future research pertaining to this discipline is necessary.

Individuals who desire to quit smoking and drinking concurrently could represent a population which should be targeted by treatment programs as the majority of individuals may opt to achieve smoking cessation during or after the resolution of alcoholism (Ellingstad, et al., 1999). Addiction programs which incorporate alcohol abstinence in

conjunction with smoking cessation could lead to favourable changes in both unhealthy behaviours by offering cognitive behavioural techniques that are similar across both behaviours (Burling & Ziff, 1988; Miller, et al., 1983). Hence, a transfer effect between these two behaviours may ensue. Furthermore, adopting and maintaining a healthy behaviour may diminish specific cues that are associated with additional behaviours (Ellingstad, et al., 1999). Consequently, favourable changes in both behaviours may transpire from the enrolment in such treatment programs (J. J. Prochaska, et al., 2004).

5.6.4 Summary of Multiple Health Behaviours:

The current analysis observed a significant interrelationship between specific health behaviours; leisure-time physical activity energy expenditure and smoking as well as alcohol consumption and smoking. These weak, but significant correlations between behaviours suggest that favourable changes in one health behaviour were significantly associated with positive changes in additional health behaviours. The fact that specific health behaviours demonstrate a tendency to interrelate suggests that one behaviour may act as a gateway behaviour; "a behaviour that, when intervened upon, has a positive influence on other behaviour changes" (Nigg, et al., 2002, pg. 676). Thus, health professionals can no longer consider health behaviours to be independent, but rather interrelated. Therefore, adopting smoking cessation may provide a teachable moment in which individuals implement additional favourable behaviours including participation in leisure-time physical activity and/or partaking in moderation or abstinence of alcohol. Unfortunately, the association between alcohol consumption and leisure-time physical activity energy expenditure did not reach statistical significance.

The fact that health behaviours interrelate could be attributed to complementary mediating cognitive-behavioural mechanisms that are mutual among behaviours (Bock, et al., 1998; T. K. King, et al., 1996). As a favourable change in one health behaviour transpires, changes in cognitive-behavioural mechanisms could initiate the adoption of additional healthy behaviours (Bock, et al., 1998; Boyle, O'Connor, Pronk, & Tan, 2000; T. K. King, et al., 1996; Unger, 1996). Therefore, the success of behavioural interventions may depend on the inclusion of techniques and strategies that enhance cognitive-behavioural mechanisms. Potentially, mastery could represent a cognitive-

behavioural mechanism that facilitates multiple behavioural changes. Such potential is discussed in subsequent sections. As public health programs accept the notion that health behaviours are interrelated, the impact on the health and well-being at the population level could be substantial.

It is important to acknowledge that while the majority of cross behavioural covariances had reached statistical significance, many of the correlations would be considered weak. However, the interpretation of correlation coefficients is often subjective and varies from one discipline to the next (Norman & Streiner, 2000). In addition, this is not the first study to report weak associations between multiple behaviours (Boyle, et al., 1998; Garrett, et al., 2004; Lippke, et al., 2012). In fact, weak correlations between health-promoting behaviours such as physical activity and health-risk behaviours including alcohol consumption or smoking are not unusual (Lippke, et al., 2012). Furthermore, multiple behavioural changes can be difficult to achieve without an intervention that is tailored towards the motivational readiness of its participants. For these reasons, in this observational study, the magnitude of each cross-behavioural correlation was expected to be small. Evaluating how individuals adopt and maintain healthy behaviours in a natural environment is an essential step in understanding the behavioural change process (J. O. Prochaska, et al., 1992). Consequently, the findings of the present study are intended to be exploratory and to guide the future development of public health programs and strategies. Had similar correlations been evaluated in a multiple health behaviour change intervention, the strength of such correlations may have been greater (Emmons, Shadel, et al., 1999). Conceivably, the observed significant correlations could be attributed to the substantial sample size that was recruited for this study. Although caution should be considered in the interpretation of these findings, this analysis indicates that a weak association exists between health behavioural changes which may substantially effect mortality and quality of life of individuals at the population level.

5.6.5 Implications of Findings:

The occurrence of co-variation between health behaviours can have numerous implications. Perhaps the most obvious benefit of co-variation would be a reduction in the likelihood of encountering morbidity and mortality (Chang, et al., 2001; Haveman-

Nies, et al., 2002; Knoops, et al., 2004; Meng, et al., 1999). As quality of life and longevity are enhanced by the adoption of multiple healthy behaviours, improvements in workplace productivity as well as reductions in worker's compensation claims and health care costs would certainly ensue (Edington, 2001). The co-variation of health behaviours may also provide health professionals with an efficient strategy for managing and/or treating multiple health behaviours. Health professionals can concentrate their time and resources on enhancing one behaviour as opposed to improving two behaviours (Pronk, Peek, et al., 2004; Tucker & Reicks, 2002). For example, by assisting individuals in achieving smoking cessation, health professionals could indirectly influence changes in alcohol consumption as well as leisure-time physical activity energy expenditure. Furthermore, if co-variation occurs in a sequential fashion, multiple behavioural programs could provide an opportunity for individuals to choose which behavioural changes are initially implemented (de Vries, Kremers, et al., 2008). This may bring about greater success in achieving behavioural changes (Ampt, et al., 2009; Berg, et al., 2012; Campbell, et al., 2000; Strecher, et al., 2002).

It is also hopeful that these findings will inform and direct both government as well as private agencies as to where monetary funding should be allocated. Health Canada may decide that the re-assignment of funding from single to multiple behavioural interventions would be more practical and sensible for Canadians. Furthermore, these findings may convince agencies to financially support specific behavioural interventions. One option that appears promising would be incorporating smoking cessation with the promotion of physical activity or alcohol abstinence. For example, in 2013, Statistics Canada estimated nearly 30 million individuals over the age of 14 residing in Canada (Statistics Canada, 2013). According to the findings of this study, 14% of the Canadian population are characterized as physically inactive smokers. This would be equivalent to approximately 4.1 million Canadians. If only 10% of these individuals achieve co-variation in these two behaviours, the implications on morbidity, mortality, and health care expenditures could be substantial. A similar case could be made for smokers who consume excessive quantities of alcohol. The current findings suggest that 1% of the general population or approximately 295,000 Canadians simultaneously participate in excessive alcohol consumption and tobacco use. Once again, if only 10% of these

individuals are successful in achieving co-variation, the impact on public health could be considerable. If the current findings influence the dissemination of government funding, they may consequently induce future policy decisions and recommendations.

Although multiple behavioural change programs appear to be a promising avenue for public health, a number of challenges will need to be addressed before the development and implementation of such programs can commence. One challenge that continues to hinder behavioural change research is the fact that health behaviours are often viewed within isolated silos representing individual entities rather than being inter-related (Hale & Viner, 2012; Orleans, 2005; J. O. Prochaska, 2008). However, the findings of this study provide evidence to suggest that this perspective is dated and perhaps no longer relevant. There is a sense of urgency among researchers and policymakers to break away from traditional beliefs that address health behaviours independently of one another (Orleans, 2004, 2005; Pronk, Peek, et al., 2004). Such beliefs leave providers, program planners, and policymakers with few options to effectively assist, counsel, educate, and treat the majority of the general population who possess multiple unhealthy behaviours (Orleans, 2005). In recent years, researchers and policymakers have been called upon to collaborate with one another to develop comprehensive multi-disciplinary initiatives and strategies that facilitate multiple health behaviour change (Atkins & Clancy, 2004; Jordan, Ory, & Goldman Sher, 2005; J. O. Prochaska, 2005; S. Solomon & Kington, 2002). The collaboration of health professionals across multiple disciplines would be beneficial as individuals could contribute and share their own unique set of resources, concepts, strategies, and expertise (S. D. Solomon, 2005). This concept of collaboration could be particularly essential for excessive alcohol consumption and tobacco use. Since alcohol consumption and smoking demonstrate an inter-relationship, treatment for both behaviours may necessitate the incorporation of individuals with an expertise in addictions as cues related to alcohol consumption may trigger a relapse in smoking and vice versa.

If public health professionals and policymakers recognize that health behaviours are inter-related as opposed to independent entities, the development of new and innovative behavioral change theories will be essential in explaining how, when, and why multiple behavioural changes can be facilitated (Orleans, 2005). Theory-comparison may provide

valuable insight into this process (Nigg, et al., 2002). Theory-comparison allows for the evaluation and integration of multiple theories simultaneously (Nigg, et al., 2002). This is essential for numerous reasons. First, theory A may explain motivating factors that promote the adoption of healthier behaviours, while theory B can provide an understanding into how individuals can maintain such favourable changes (Nigg, et al., 2002). Independently, these theories describe specific aspects of the behavioural change process. However, through theory-comparison, one may compose a new theory that fully explains the process of multiple behavioural change (Nigg, et al., 2002). Furthermore, existing theories may not completely explain differences in behavioural changes necessitating the development of new theories (Nigg, et al., 2002).

Although the health benefits of physical activity are well known, a significant proportion of the general population are unable or unwilling to participate in adequate levels of leisure-time physical activity. The findings of this study reiterate this perspective as over 70% of this Canadian sample did not satisfy the recommended guideline for a physically active lifestyle at any data collection period. For this reason, public health professionals need to focus their attention and resources on developing innovative approaches in motivating the general population to participate in sufficient levels of physical activity (Talbot, et al., 2003). Considering that a substantial proportion of the general population is physically inactive as well as the health risks associated with the adoption of such a lifestyle, public health programs should reflect on devoting as much effort and resources into increasing physical activity levels as they put forth into implementing other behavioural changes such as smoking cessation. Once a physically active lifestyle is adopted, the findings of this study suggest that positive behavioural changes in tobacco use are more likely to ensue among daily and occasional smokers.

5.7 Demographic Covariates:

Demographic characteristics can have a substantial influence on the behavioural change process. These characteristics are often indicative of whether individuals possess the willingness and/or capability to adopt and/or maintain behavioural changes (Boyle, et al., 1998). Such characteristics may include gender, chronological age, marital status, education, income, and BMI (T. A. Barnett, et al., 2008; Fine, et al., 2004; Li, et al.,

2009; Poortinga, 2007b; Prattala, et al., 1994; Schmitz, French, & Jeffery, 1997; Vandelanotte, et al., 2008). The effect that each demographic characteristic had on the interrelationship of multiple health behaviours is discussed in the following paragraphs. For the purpose of the current analysis, gender and age were considered time-invariant covariates, while marital status, education, income adequacy, and BMI were deemed time-varying covariates.

5.7.1 Gender:

It was not surprising that gender was significantly associated with alcohol consumption, leisure-time physical activity, and smoking as the effects of gender on health behaviours are well established. Males often demonstrate a tendency to possess a greater number of unhealthy behaviours (Emmons, McBride, Puleo, Pollak, Marcus, et al., 2005; Fine, et al., 2004; Li, et al., 2009). More specifically, compared to females, males report a greater likelihood of consuming more alcohol (Allison, et al., 1999; Casswell, Pledger, & Hooper, 2003; Klein-Geltink, et al., 2006; Schuit, et al., 2002) and partaking in tobacco use (Klein-Geltink, et al., 2006; Leatherdale & Shields, 2009; Li, et al., 2009). Physical activity is the exception as males are typically more physically active than females (T. A. Barnett, et al., 2008; Craig, et al., 2007; Klein-Geltink, et al., 2006; Leatherdale, Manske, Faulkner, Arbour, & Bredin, 2010). In addition to possessing healthier behaviours at the outset of the NPHS, females also exhibited more favourable behavioural trajectories compared to their male counterparts. Over time, females reported a slower increase in alcohol consumption and a more rapid positive growth in physical activity. However, females demonstrated a flatter or slower decline in the use of tobacco products which coincides with the findings of others (Vlasoff, et al., 2008).

5.7.2 Chronological Age:

Older individuals have a tendency to report a greater number of healthier behaviours (Berrigan, et al., 2003; Fine, et al., 2004; Poortinga, 2007b; Rosal, et al., 2001). By their early fifties, individuals often meet the recommended guidelines for various health behaviours including alcohol consumption, physical activity, and smoking (Berrigan, et al., 2003). The current analysis found that chronological age had a significant role in

alcohol consumption and smoking behaviour. Older Canadians demonstrated a slower rate of positive growth in alcohol consumption and a steeper decline in smoking behaviour compared to younger Canadians. Previous research has observed declines in both alcohol consumption and tobacco use with age (Leatherdale & Shields, 2009; Moore, et al., 2005; Shaw, et al., 2011; Shields, 2007a; van Loon, Tijhuis, Surtees, & Ormel, 2005). In fact, age can have such a substantial effect on tobacco use that older individuals are more likely to achieve smoking cessation (Hymowitz, et al., 1997).

In regards to leisure-time physical activity, younger individuals have been known to possess activity levels that surpass their older counterparts (T. A. Barnett, et al., 2008; I. M. Lee, et al., 1992; Schmitz, et al., 1997). Initially, this association was observed as older Canadians reported lower levels of physical activity. However, over subsequent cycles, older Canadians demonstrated an increase in leisure-time physical activity confirming the findings of others (I. M. Lee, et al., 1992; Steffen, et al., 2006). Although this increase in physical activity was significant, its magnitude was quite small. The latter years of one's life may provide the opportunity to dedicate more time towards a physically active lifestyle as employment and familial obligations begin to decline (Satia, et al., 2004). It is important to acknowledge that the slope of leisure-time physical activity did not reach statistical significance in the parallel process model involving alcohol consumption and physical activity. Perhaps the inclusion of alcohol consumption attenuated any potential differences in physical activity between younger and older Canadians.

5.7.3 Marital Status:

In nearly every cycle of the NPHS, marital status had a significant positive effect on both alcohol consumption and tobacco use. Unmarried Canadians, including those who were single, divorced, separated, or widowed, consumed higher quantities of alcohol as well as reported greater use of tobacco. The importance of conducting oneself as a role model for their children, married individuals may promote healthy behaviours by choosing to participate in abstinence or moderation of alcohol consumption and smoking. This may explain why the transition from being single to married is accompanied by a reduced likelihood of partaking in excessive alcohol consumption and tobacco use (Karlamangla,

et al., 2006; McDermott, et al., 2004). Furthermore, being single may provide more frequent opportunities to socialize with friends. Such social gatherings may contribute to regular consumption of alcohol and/or tobacco use. Marital status was also positively associated with physical activity as unmarried Canadians were expending more energy during their leisure-time physical activity. Perhaps, married individuals may encounter familial obligations and greater responsibilities which do not provide sufficient time to participate in leisure-time physical activity. These associations between marital status and health behaviours are not uncommon and have been previously observed by others (Broms, Silventoinen, Lahelma, Koskenvuo, & Kaprio, 2004; Karlamangla, et al., 2006; Leatherdale & Shields, 2009; McDermott, et al., 2004; Moore, et al., 2005; Schmitz, et al., 1997; van Loon, et al., 2005).

5.7.4 Education:

Education is believed to be a strong predictor of multiple healthy behaviours (Berrigan, et al., 2003; Emmons, McBride, Puleo, Pollak, Marcus, et al., 2005; Fine, et al., 2004; Li, et al., 2009; Prattala, et al., 1994; Pronk, Anderson, et al., 2004; Rosal, et al., 2001). However, the current findings suggest this was not necessarily the case for all health behaviours. Education was significantly associated with alcohol consumption during every cycle of data collection such that Canadians who had acquired at least some post-secondary schooling consumed higher quantities of alcohol. In the early cycles, education demonstrated a tendency to be negatively associated with leisure-time physical activity. However, during the latter cycles, a positive relationship had emerged between education and leisure-time physical activity suggesting that those individuals who had acquired higher academic achievements expended greater amounts of energy expenditure during their leisure-time. One explanation for this finding could be that highly educated individuals often engage less physically demanding occupations. Since their occupation does not provide adequate levels of physical activity, such individuals may feel that they need to acquire more sufficient levels of physical activity. It is during their leisure-time in which they have their only opportunity to be physically active. Others have also observed a positive association between education and health behaviours; alcohol consumption (Moore, et al., 2005) and physical activity (Schmitz, et al., 1997). Unlike

alcohol consumption and leisure-time physical activity energy expenditure, one's educational achievement appeared to have a lesser influence on smoking behaviour. Initially, the association between education and tobacco use was positive before becoming negative in the latter cycles. This transition from a positive to a negative association could be attributed to individuals acquiring more awareness and education about the harmful effects of tobacco use as they age. However, it is important to acknowledge that significant associations between education and tobacco use were only observed during half of the data collection cycles. Although this finding was unexpected, others have also been unable to observe an association between education and smoking cessation (Hymowitz, et al., 1997).

5.7.5 Income Adequacy:

The adherence to multiple health behaviours is associated with higher household income (Berrigan, et al., 2003; Li, et al., 2009). The current analysis found that income adequacy was perhaps most influential on alcohol consumption and physical activity. Both alcohol consumption and leisure-time physical activity were positively associated with income adequacy suggesting that Canadians earning higher incomes reported greater levels of alcohol consumption and leisure-time physical activity energy expenditure. Positive associations between income and alcohol consumption (Moore, et al., 2005) as well as physical activity (T. A. Barnett, et al., 2008; Craig, et al., 2007; Iribarren, Luepker, McGovern, Arnett, & Blackburn, 1997; Pomerleau, Pederson, Ostbye, Speechley, & Speechley, 1997) have been acknowledged by others. Although occurring during the latter cycles, the negative association between income adequacy and tobacco use implied that Canadians earning higher incomes demonstrated lower tobacco use in the form of moderation or complete abstinence. The relationship between household income and tobacco use (Iribarren, et al., 1997; D. S. Lee, et al., 2009) as well as smoking cessation (Hymowitz, et al., 1997) has been previously confirmed. The fact that this association was only present during half of the data collection cycles may suggest that income adequacy was not a strong predictor of tobacco use.

Education and income are two demographic characteristics that are often used inter-changeably. After all, it is reasonable to believe that a positive association exists between

both attributes. However, this may not always be the case as tradesmen can earn high incomes while spending relatively few years in an academic institution. In addition, in the current analysis, income was not simply calculated on the basis of total annual household income, but this variable took into consideration the number of individuals residing in the household (Statistics Canada, 2008). It was interesting to note that at various cycles, it was not unusual for income adequacy to be significantly associated with a particular behaviour, while education demonstrated no such relationship and vice versa.

5.7.6 Body Mass Index:

Derived from one's weight and height, BMI is often used as an indicator of body fat. Therefore, it is not surprising that BMI, to some extent, was associated with alcohol consumption, leisure-time physical activity, and smoking. The present analysis observed a significant negative relationship between BMI and leisure-time physical activity as well as smoking. These findings, which are in agreement with previous research (T. Gordon & Doyle, 1986; Kimokoti, et al., 2010; Lahti-Koski, Pietinen, Heliovaara, & Vartiainen, 2002; Laitinen, Pietilainen, Wadsworth, Sovio, & Jarvelin, 2004; Schmitz, et al., 1997; Zimmermann, Ekholm, Gronbaek, & Curtis, 2008), indicate that obese or overweight Canadians reported less physical activity and reduced use or abstinence from tobacco products. In the earlier cycles of the NPHS, previous findings were confirmed (Lahti-Koski, et al., 2002; Laitinen, et al., 2004) as a positive association involving BMI and alcohol consumption was observed. However, during the sixth cycle, this significant relationship became negative suggesting that obese or overweight Canadians consumed lower levels of alcohol.

5.7.7 Summary of Demographic Covariates:

Identifying demographic and cognitive behavioural characteristics that are associated with multiple unhealthy behaviours could assist public health professionals in targeting individuals who are at greatest risk of chronic disease as well as those who are motivationally ready to adopt and maintain healthy behavioural changes (Poortinga, 2007b; Schuit, et al., 2002). It has been suggested that public health efforts and resources should be targeted towards disadvantaged individuals as such individuals often appear to

partake in multiple unhealthy behaviours simultaneously (Babor, Sciamanna, & Pronk, 2004; Boniface, et al., 2001; Li, et al., 2009; Orleans, et al., 1999; Schuit, et al., 2002). This analysis confirms that participating in unhealthy behaviours is generally associated with unfavourable demographic characteristics; lower education and lesser income adequacy. Therefore, it is recommended that multiple health behaviour interventions be specifically tailored and intended for such disadvantaged individuals.

While demographic characteristics may identify which individuals possess specific unhealthy behaviours, such characteristics do not appear to impede or hinder the interrelationship of health behaviours. Despite the fact that behavioural correlations may have been slightly attenuated after accounting for demographic characteristics, they continued to exhibit comparable strength to those correlations that were unadjusted for demographic characteristics. Likewise, covariances that were significant in the unadjusted models remained significant in the adjusted models. The fact that estimates for behavioural correlations and covariances remained relatively unchanged after adjusting for demographic characteristics discredits the perception that specific individuals are incapable of modifying unhealthy behaviours. One's gender, chronological age, marital status, educational level, income status, or body composition appeared to be irrelevant in the occurrence of co-variation. From the perspective of health professionals and policymakers, these findings are advantageous for several reasons. First, the success of strategies and public health programs in implementing multiple behavioural changes is not dependent upon demographic characteristics of individuals. Successful behavioural changes can be facilitated throughout the general population which enhances the reach of such programs. Second, since specific demographic characteristics are relatively difficult or impossible to alter, strategies and programs need not be concerned with attempting to alter these characteristics. This will allow the opportunity to dedicate greater resources towards characteristics that are more easily modifiable and could provide greater success in promoting co-variation.

5.8 Mediating Effects of Mastery:

Mediation is the process by which a third variable, known as a mediator, either partially or fully explains the causal relationship between the independent and dependent

variables. Consequently, the inclusion of a mediating variable attenuates the coefficient between the independent and dependent variables. Alternatively, a moderator refers to a variable that has no part in the causal relationship, but rather changes the direction and/or strength of an association between the independent and dependent variables (Baron & Kenny, 1986; MacKinnon, et al., 2007). Evaluating potential mediating variables may provide essential information pertaining to the causal relationship between such variables (MacKinnon, et al., 2007). In a single mediator model, the independent variable influences the mediator and in succession the mediator effects the dependent variable (MacKinnon, et al., 2007).

Mastery refers to the "extent to which one regards one's life-chances as being under one's own control in contrast to being fatalistically ruled" (Pearlin & Schooler, 1978, pg. 5). Similar to self-efficacy and locus of control, personal control is a fundamental component of perceived mastery (Pearlin & Pioli, 2003). However, unlike locus of control, mastery tends to centre around controlling events that the individual perceives as of great importance to their life as opposed to circumstances related to their environment (Pearlin & Pioli, 2003). In the current analysis, mastery was believed to act as a potential mediator in the interrelationship of health behaviours. Over the duration of the NPHS, mastery demonstrated a small, but significant decline among Canadians. This longitudinal trend coincides with the findings from previous empirical research (Mirowsky, 1995; Pearlin, Nguyen, Schieman, & Milkie, 2007). Middle age has been shown to represent an important period in one's lifetime as perceived control begins to diminish at this point (Mirowsky & Ross, 2007). The findings of this analysis provide some evidence to support the conclusions of Mirowsky and Ross (2007).

As was the case with each of the three health behaviours, a linear model was used to depict the trajectory of mastery. Although the inclusion of an additional growth factor may have provided superior fit over the linear model, the CFI and RMSEA of the linear mastery model were within the appropriate cut-off values; ≥ 0.96 and ≤ 0.05, respectively. The SRMR could have been improved, however it also remained within an acceptable range (Hu & Bentler, 1999). The interpretability of more complex mediation models was also a concern, thereby providing further justification for modeling mastery as a linear trajectory.

Perceived mastery seemed to have the most consistent effect on leisure-time physical activity as well as smoking. In both parallel process models, mastery appeared to have a positive and significant influence on leisure-time physical activity. Allison et al. (1999) was unable to detect a relationship between mastery and leisure-time physical inactivity, while Cairney et al. (2005) observed a weak, albeit significant, correlation between these aforementioned variables. It is important to consider that mastery may influence physical activity longitudinally as opposed to within a cross-sectional design. Furthermore, Allison et al. (1999) had accounted for the effects of demographic and/or social characteristics in their analysis. Perhaps the association between mastery and leisure-time physical activity would no longer reach statistical significance after accounting for such characteristics. In addition to influencing physical activity, mastery, in turn, was affected by physical activity verifying the findings of others (Sorensen, 1997; Sorensen, et al., 1997). Unlike leisure-time physical activity, changes in smoking neither initiated nor resulted from changes in mastery. This association has also been observed by others (Allison, et al., 1999; Sneed, et al., 2001). Perhaps, in the case of tobacco use, mastery may not provide individuals with sufficient self-control, discipline, and resolve to achieve cessation. Alcohol consumption demonstrated an interesting association with perceived mastery. Although changes in alcohol consumption had significantly and positively influenced changes in perceived mastery, changes in mastery had no significant effect on changes in alcohol consumption.

Unfortunately, for the majority of mediation models, mastery was unsuccessful in mediating the co-variation of health behaviours. Some have suggested that mastery denotes a more universal evaluation of perceived control rather than assessing specific phases of health behaviours (Allison, et al., 1999; Cairney, et al., 2009). For this reason, mastery is not perceived as significantly associated with health behaviours (Allison, et al., 1999; Sneed, et al., 2001). Furthermore, mastery is recognized as an essential mediating component of the stress process (Avison & Cairney, 2003). Therefore, while mastery may support individuals in coping with stressful events, this cognitive mechanism may not actually assist in the initiation or maintenance of such behavioural changes. Finally, according to the Theory of Planned Behaviour, perceived behavioural control can influence behaviours either directly or indirectly through one's intentions

(Ajzen, 1991). Perhaps, as a potential mediator, mastery was inadequate in altering one's intentions to adopt favourable changes in excessive alcohol consumption and tobacco use.

Interestingly, mastery appeared to demonstrate the properties of a suppressor variable rather than a mediating variable. A suppressor variable is known to conceal the relationship between causal and outcome variables (Cheung & Lau, 2008). The criteria for establishing a suppresser variable within a causal relationship are twofold: 1) the indirect and total effects demonstrate opposing signs (Rucker, et al., 2011), and 2) the direct effect is greater than the total effect (Rucker, et al., 2011). In the alcohol consumption and smoking model, mastery had fulfilled both of these criteria and thus represented a suppressor variable. In the physical activity and smoking model, mastery had only satisfied the first criterion and therefore could potentially act as a suppressor variable (Rucker, May 17, 2013). In both cases, it could be worthwhile for health promotion programs to include strategies that promote mastery as the association between the independent and dependent variables is strengthened with the addition of mastery (Rucker, et al., 2011).

Notwithstanding the inability of mastery to act as a potential mediator in the majority of models, this analysis concluded that mastery mediates the association in which changes in alcohol consumption initiates changes in leisure-time physical activity. Increasing one's alcohol consumption appeared to provide Canadians with a sense of control which sequentially results in favourable changes in leisure-time physical activity. It was surprising to observe a positive association between alcohol consumption and mastery. Perhaps higher levels of education and/or income adequacy that were associated with consuming greater quantities of alcohol provided individuals with a sense of control over events that were deemed important. On the other hand, it is conceivable that any improvements in mastery may not be genuine but rather a false sense of control that is triggered by excessive alcohol consumption. Public health programs and strategies which emphasize moderation and/or abstinence of alcohol could reduce one's perception of control over events thereby reducing leisure-time physical activity levels. Therefore, programs that wish to promote physical activity following a reduction or abstinence in

alcohol consumption may need to focus their attention on additional cognitive behavioural mechanisms instead of mastery.

The fact that both the indirect and direct effects between alcohol consumption and leisure-time physical activity reached statistical significance suggests that mastery partially mediates the relationship between these two health behaviours (MacKinnon, et al., 2007). Although full mediation was not achieved, one should not discount the valuable contribution that mastery has in the relationship between alcohol consumption and leisure-time physical activity (Rucker, et al., 2011). As multiple behavioural change is quite complex, it is unlikely that a single mediating cognitive-behavioural mechanism such as mastery would provide a complete explanation in the association between alcohol consumption and leisure-time physical activity. Other cognitive behavioural determinants may have greater success in changing health behaviours. One such mechanism could be self-efficacy (Bock, et al., 1998; DiClemente, et al., 1985; T. K. King, et al., 1996; O'Hea, et al., 2004; Von Ah, Ebert, Ngamvitroj, Park, & Kang, 2004) as it is often considered essential in the initiation of behaviour change (Love, et al., 1996). Future research should evaluate the potential mediating effects of self-efficacy in the interrelationship of multiple health behaviours. As the presence of multiple unhealthy behaviours continues to be quite prevalent within the general population, the identification and targeting of mediators that are associated with the adoption and maintenance of positive behavioural changes will be essential (Costakis, et al., 1999; Dierker, et al., 2006).

5.9 Strengths:

Although cross-sectional studies have provided valuable insight into the interrelationship of multiple health behaviours, such study designs only provide a “snapshot” of associations between health behaviours. The inability to account for change in health behaviours is an essential limitation. Accordingly, over the last several decades, research has acknowledged the necessity to evaluate the interrelationship of multiple health behavioural change through a longitudinal study design (Boudreaux, et al., 2003; Costakis, et al., 1999; Garrett, et al., 2004; Herrick, et al., 1997; Nigg, et al., 1999; Rosal, et al., 2001). Longitudinal studies are not constrained to such a limitation as this type of

research design involves the collection of repeated measures of information on the same individual over multiple time periods. As such, longitudinal studies appear to be a more appropriate method to evaluate co-variation and could represent the future of multiple health behaviour change (Blakely, et al., 2004).

Commencing in 1994/1995 with subsequent cycles occurring biennially, the current analysis had utilized seven data collection periods representing 12 years of health behaviour information. The duration of time that this study encompasses surpasses that of previous observational longitudinal studies (Audrain-McGovern, et al., 2003; Breslau, et al., 1996; Dierker, et al., 2006; Jessor, et al., 2006; Kahler, et al., 2009; Laaksonen, et al., 2002; McDermott, et al., 2004; Murray, et al., 2002; Nagaya, et al., 2007; Perkins, et al., 1993; Saules, et al., 2004). This presents a greater opportunity to not only evaluate health behavioural changes, but to monitor the trajectories of these health behaviours over a considerable period of one's lifetime.

In addition to the length of time in which data was collected, the number of evaluation cycles that were administered should also be considered a strong point of the current analysis. In the past, naturally occurring longitudinal studies have typically measured health behaviours on two occasions (Breslau, et al., 1996; Carmelli, et al., 1993; T. Gordon & Doyle, 1986; Kahler, et al., 2009; Laaksonen, et al., 2002; McDermott, et al., 2004; Murray, et al., 2002; Perkins, et al., 1993). In contrast to these research studies, the current analysis had incorporated seven data collection periods. By utilizing numerous cycles of data collection, this study offers several advantages that are unfeasible for studies that have incorporated only two periods of data collection. As additional health behaviour information is collected, the precision of parameter estimates is enhanced (Francis, et al., 1991; Rimm & Stampfer, 2004; D. Rogosa, et al., 1982). Additional improvements in the precision of the parameter estimates could also be achieved by the relatively close spacing of the observation cycles (Francis, et al., 1991). Furthermore, the incorporation of numerous assessment periods permits the opportunity to evaluate various growth trajectories (Francis, et al., 1991). It has been reported that two data collection cycles are inadequate to fit a linear change (MacCallum, et al., 1997; Streiner, 2008), while more complex non-linear trajectories may require more than five measurement occasions (MacCallum, et al., 1997). Thus, the evaluation of linear and non-linear

change is not a feasible option for researchers that have collected information at two time periods.

The recruitment of a representative sample continues to be a challenge that will need to be addressed within future multiple health behaviour research (Nigg, et al., 2002). The evaluation of the interrelationship of multiple health behaviour change within various subgroups including women (Perkins, et al., 1993), Japanese males (Nagaya, et al., 2007), younger individuals (Breslau, et al., 1996), university students (Keller, et al., 2008), middle-aged male twins (Carmelli, et al., 1993), individuals with at least one chronic illness (Boudreaux, et al., 2003; Boyle, et al., 1998), as well as pregnant women (Pirie, et al., 2000) may generate findings that are not applicable to the general population. The recruitment of a large nationally representative population-based sample of over 15,000 Canadians which included individuals from diverse subgroups of the general population enhanced the strong external validity of these findings.

From the perspective of policy markers, the utilization of dichotomous or categorical variables would be preferred as the designated cut-off criteria indicating the presence or absence of a healthy lifestyle would be fairly straightforward to interpret and easily conveyed to the general population. However, it is believed that the use of continuous variables had improved the ability of this study to detect changes, both favourable and unfavourable, in alcohol consumption, leisure-time physical activity energy expenditure, and smoking behaviour. By relying on specific health guidelines, behavioural changes would otherwise be unnoticed unless one was to surpass the established cut-off criteria. This study provides a good example of this concept. As a dichotomous variable, notwithstanding the role of attrition, only a small proportion of Canadians, 8.0%, had achieved smoking cessation from 1994/1995 to 2006/2007. However, overlooked by this dichotomous variable were individuals who reported a reduction in tobacco use but were unable to achieve smoking cessation. By employing a continuous variable, those individuals who accomplished even the slightest behavioural change were recognized as adopting a healthier smoking behaviour. Therefore, continuous variables are more sensitive in identifying behavioural changes.

Unlike traditional statistical methods for evaluating longitudinal change, latent growth curve analysis does not exclude individuals with incomplete data (Streiner, 2002, 2008;

Stull, 2008). Instead, the use of maximum likelihood estimation can fit linear and non-linear trajectories based upon all available observations (Bollen & Curran, 2006; B. Muthen, Kaplan, & Hollis, 1987; Wu, et al., 2009). This is an important advantage of using growth curve modelling as attrition is often common among longitudinal study designs. Aside from reducing attrition bias, additional benefits of utilizing latent growth curve analysis include the ability to incorporate numerous and unequally spaced cycles of data collection (Francis, et al., 1991; Willett & Sayer, 1996) as well as the capability to estimate parameters that were free from measurement error (Stull, 2008).

5.10 Limitations:

In spite of the numerous strengths associated with this study, several limitations should be considered that are not unusual for longitudinal survey research. One limitation that is often associated with the utilization of a longitudinal study design is attrition (Lilienfeld & Stolley, 1994). This study was not exempt from such a limitation. At the completion of the seventh cycle of the NPHS, only 51% of Canadians had provided valid responses for all variables of interest. According to Table 12, Canadians who completed the household component questionnaire at the seventh assessment period were more likely to be younger, married or formerly married, with higher levels of education, income adequacy, and BMI scores compared to their counterparts who failed to participate in the seventh cycle. Furthermore, mastery, alcohol consumption, smoking behaviour, as well as the number of chronic conditions possessed also appeared to distinguish between participation membership. These significant associations suggest that specific individuals could be underrepresented within this sample. Consequently, over time, generalizing these findings back to the broader population could be difficult as the sample may no longer represent the population from which it was recruited. In anticipation of this limitation, sampling weights were employed for this statistical analysis. Calculated by Statistics Canada, these sampling weights indicate the probability that an individual was selected at the initial assessment (Statistics Canada, 2008). Thus, each individual in the sample represents themselves as well as numerous other Canadians who were not recruited within the sample (Korn & Graubard, 1991; Statistics Canada, 2008). The employment of sampling weights should provide estimates that are similar to those that

would be calculated for the entire population (Korn & Graubard, 1995). Statistics Canada recommends the use of sampling weights for any statistical analysis that is performed using the longitudinal NPHS (Statistics Canada, 2008). With the utilization of such sampling weights, the representativeness of the Canadian target population is preserved at the first cycle (Statistics Canada, 2008). Therefore, the sampling weights contributed to the strong external validity of the study. However, in subsequent cycles, the representativeness of this sample could be suspected as suggested by the logistic regression model in Table 12.

Studies involving the surveillance of alcohol consumption and physical activity often depend on self-reported measures (Finney, et al., 2003; Katzmarzyk & Tremblay, 2007). However, one drawback that is frequently cited when relying on self-reported measures is the possibility that participants may provide socially desirable responses (Barrett, et al., 1995; Katzmarzyk & Tremblay, 2007; Satia, et al., 2004). Known as social desirability bias, the tendency for participants to provide responses that they believe others will deem as favourable may underestimate unhealthy behaviours such as alcohol consumption and smoking behaviour, while overestimating healthy lifestyles including physical activity. Although self-reported measures may threaten internal validity, they have been shown to be valid in monitoring alcohol consumption (Del Boca & Darkes, 2003), physical activity (Craig, et al., 2002), and smoking behaviour (Yeager & Krosnick, 2010). Perhaps the most precise method in assessing health behaviours would involve a series of biochemical and physiological techniques. However, such verification methods would be extremely time consuming, expensive, invasive, and an exhaustion of resources. Such techniques are often considered unfeasible for large population-based samples such as the NPHS (Emmons, Shadel, et al., 1999; Oenema, Brug, Dijkstra, de Weerdt, & de Vries, 2008). Therefore, research that involves the recruitment of large population-based samples have very few options and typically rely upon the use self-reported measures to assess health behaviours (Emmons, Shadel, et al., 1999).

Recall decay, a form of response error, could also be introduced to research that relies on self-reported measures. Recall decay refers to "a decline in the ability to recall an event as the event recedes in time" (R. A. Johnson, et al., 1998, pg. 356). This form of response bias may compromise the validity within this study. However, recall decay may

have been minimized as the time frame in which health behaviours were assessed was relatively short. Smoking behaviour was measured at the present time. Alcohol consumption was assessed over the previous week prior to the interview, while individuals were asked to recall information from the previous three months for leisure-time physical activity energy expenditure. Since individuals were asked to recall information pertaining to recent participation in health behaviours, it is likely that any recall decay that may have been experienced would have been minimal.

An additional dilemma associated with attrition pertains to missing data. Missing data has proven to be challenging when utilizing traditional statistical methods as individuals with missing responses are excluded from any analysis (Gueorguieva & Krystal, 2004). When a substantial proportion of one's sample is excluded from the analysis, bias could be introduced as the findings are based upon individuals who may no longer be representative of the original sample (Schafer & Olsen, 1998). Over the years, several techniques have been developed to cope with missing data. The use of maximum likelihood estimation fits a trajectory based upon all available observations (Bollen & Curran, 2006; Wu, et al., 2009). Consequently, individuals who provide at least one valid response are included in the analysis. Maximum likelihood estimation provides non-bias estimates even if the assumption of data missing completely at random is violated (B. Muthen, et al., 1987). Another approach for dealing with missing data is multiple imputation. With multiple imputation, missing data is replaced with plausible responses in multiple datasets (Schafer & Olsen, 1998). Such plausible responses are predicted from reported answers of other individuals in the sample (Schafer & Olsen, 1998). In the current analysis, multiple imputation was only utilized in the demographic time-varying covariate models as a solution in preventing listwise deletion. Had multiple imputation not been used in the aforementioned covariate models, these findings may have been susceptible to bias. It was possible to use multiple imputation throughout the entire analysis of the current study. However, in large sample sizes, whenever possible, maximum likelihood estimates are recommended over multiple imputation (Schafer & Olsen, 1998). Although one could argue that missing data may have influenced the findings of this study, a supplementary analysis was performed in which missing data was replaced with imputed data. As outlined in Appendix 1, few differences in

behavioural covariances and correlations were identified between the current findings and the results of the imputed data. The fact that similarities were observed between the original and imputed findings suggests that attrition bias had minimal influence on the current findings. Consequently the external validity of the study remained strong.

The representativeness of the current sample was difficult to establish. Comparing demographic characteristics with previous studies would be challenging as different time frames and the use of various demographic categories have been used. In previous datasets including the Canadian Community Health Survey, Statistics Canada has typically employed a stratified multi-stage design to recruit individuals from the general population with the objective of creating a representative sample. Had access been granted to use the Canadian Community Health Survey as well as its respective sampling weights, it would have been possible to conduct a comparison of the demographic characteristics. Unfortunately, such a comparison could not be performed. The use of sampling weights that were provided in the NPHS were adjusted by Statistics Canada to represent the general population at 1994/1995. Thus, with the incorporation of the sampling weights, it is reasonable to believe that the current sample was representative of the general Canadian population at the initial data collection period and contributed to the strong external validity of the study.

Maximum likelihood estimation assumes that observed variables demonstrate multivariate normality (Bollen & Curran, 2006; Preacher, et al., 2008; Stull, 2008; Wu, et al., 2009). Typically, this assumption is unrealistic (Olsson, et al., 2000). When this assumption is violated, researchers should be aware of the possibility that standard errors and significance testing could be incorrect (Bollen & Curran, 2006). As observed in Table 16, all three health behaviours violated the assumption of multivariate normality. However, maximum likelihood estimation has been shown to produce accurate estimates despite violations of normality (Olsson, et al., 2000). Furthermore, the use of bootstrap procedures that produce confidence intervals has been suggested for analyzing non-normally distributed data (Bollen & Stine, 1990). MPLUS software offers 99% bias-corrected bootstrap confidence intervals that "take non-normality of the parameter estimate distribution into account" (L. K. Muthen & Muthen, 1998-2011, pg. 647).

With regards to physical activity, this study specifically focused upon leisure-time physical activity energy expenditure. However, leisure-time physical activity represents only one domain of total energy expenditure (Jacobi, et al., 2009; Weller & Corey, 1998). Additional domains of energy expenditure that are often overlooked include occupational and household. Measures for both occupational and household energy expenditure were not considered for this analysis as they were unavailable in the seven cycles of the NPHS. Therefore, these two domains of total energy expenditure could not be assessed. The exclusion of occupational and household energy expenditure is likely to underestimate total energy expenditure as non-leisure-time energy expenditure usually accounts for a substantial amount, 40 to 82%, of one's total energy expenditure, particularly among women (Steffen, et al., 2006; Weller & Corey, 1998).

When calculating variance estimates, the multi-stage survey design of the NPHS must be taken into consideration (Statistics Canada, 2008). The use of bootstrapping weights, which is recommended by Statistics Canada, provides unbiased estimates of variances (Statistics Canada, 2008). However, this analysis was unable to employ the recommended bootstrapping weights as a bootstrapping program for growth curve models has not been developed (Statistics Canada, 2008). As bootstrap weights were not utilized in the current analysis, it is possible that standard errors and/or confidence intervals for parameter estimates were larger than if the bootstrap weights were employed. As a result, associations that were previously non-significant may have become significant had bootstrapping weights been applied. However, for the most part, this is unlikely to occur as non-significant associations tended to have p-values that were quite large. In an attempt to compensate for the inability to employ the bootstrapping weights provided by Statistics Canada, bias-corrected bootstrap confidence intervals were requested for each latent growth curve model.

MacKinnon (2008) described a technique in which mediation effects can be calculated through the use of a parallel process model. Such models involve the development of growth trajectories for the independent, mediating, and dependent variables. However, the ability to establish a causal association in mediation models that assess variables at simultaneous time periods could prove to be challenging and biased. Reverse or concurrent causation may result from such models (Selig & Preacher, 2009). As outlined

by Selig and Preacher (2009), a sequential process approach could be more appropriate for representing mediation models as the independent, mediating, and dependent variables are repeatedly measured on a sequential continuum. Arguably, this technique may not have been appropriate for this study as the independent, mediating, and dependent variables would each require a minimum of three time periods to fit a linear trajectory (MacCallum, et al., 1997; Streiner, 2008) for a total of nine assessment periods. However, at the completion of this analysis, only eight cycles of data had been collected. Consequently, it is important to acknowledge that although mastery demonstrated a significant indirect effect between alcohol consumption and physical activity, one should not disregard the fact that this finding could have been attributed to additional variables.

Finally, it is important to consider the possibility that more complex models may have shown similar or enhanced fit of the longitudinal dataset (MacCallum & Austin, 2000). The current analysis opted to develop simple unconditional and multivariate models by incorporating linear trajectories as well as covariances that were deemed necessary to answer the proposed research question. In an attempt to improve model fit, researchers may choose to include additional growth factors, pathways, or covariances. Consequently, in contrast with the proposed models in the current analysis, more complex parallel process models may reveal dissimilar associations. Although model fit could have been improved with the addition of growth factors or covariances between residual variances, the minimum cut-offs for CFI, RMSEA, and SRMR for each unconditional and multivariate model was upheld in the present analysis. MacCallum et al. (1992) recommends that "... when an initial model fits well, it is probably unwise to modify it to achieve even better fit because the modifications may simply be fitting small idiosyncratic characteristics of the sample" (MacCallum, Roznowski, & Necowitz, 1992, pg. 501). Modifications that are implemented for the purpose of enhancing model fit may result in the development of models that lack generalizability (MacCallum, et al., 1992).

5.11 Future Research:

Although the findings of this study provide significant insight into the understanding of multiple health behavioural change, they also re-affirm as well as introduce additional questions that will need to be addressed by future research. The purpose of this study

was to evaluate the interrelationship of behavioural changes within a nationally representative population-based multi-wave database. In addressing this research question, this study incorporated several methodological strengths that contributed to its novelty. The multi-wave longitudinal study design had the capability to recognize behavioural trajectories over a considerable period of one's lifespan, while contributing to the precision of calculated estimates. The use of a nationally representative sample provided greater confidence that the findings were externally valid in the general population. Assessing health behaviours as continuous variables was a more sensitive approach in identifying behavioural changes. The evaluation of mastery as a potential mediating mechanism was able to offer insight into the co-variation process. To my knowledge, this is the first epidemiological study to evaluate the inter-relationship of health behaviours using such methodological criteria. Consequentially, the integration of these strengths yields a study that is unique in comparison to previous empirical research. Future studies which employ a similar study design, sample, and outcomes are required to verify these findings.

In previous epidemiological studies, the interrelationship of multiple health behaviour change has often incorporated the evaluation of dietary intake. This analysis was unable to evaluate dietary intake as information pertaining to fruit and vegetable consumption was limited to only three of the first seven cycles of data collection. Furthermore, dietary fat intake was completely non-existent. In previous research, dietary intake has typically been evaluated with physical activity as these two behaviours are often used in conjunction for weight management programs. The interrelationship between dietary intake and physical activity is controversial (Bock, et al., 1998; Reedy, et al., 2005; W. C. Taylor, et al., 2004; Wilcox, King, Castro, & Bortz, 2000). Future research should evaluate the potential interrelationship between dietary intake and other health behaviours by incorporating a similar methodology as the present analysis; a longitudinal study design within a nationally representative population as well as the use of continuous health behaviour outcomes. Dietary intake could be an effective gateway behaviour and thus provide health professionals with an additional option in facilitating change in supplementary health behaviours.

While these findings indicate that change in one health behaviour facilitates change in another, a concern that continues to persist is how to produce the initial change in health behaviours. In other words, why do some individuals decide to change health behaviours while other individuals decide against making such changes? Surely, one should not underestimate the role that cognitive-behavioural mechanisms play in behavioural changes, particularly self-efficacy (DiClemente, et al., 1985; T. K. King, et al., 1996; O'Hea, et al., 2004). The presence of chronic diseases has also been shown to increase an individual's motivational readiness to adopt healthier behaviours suggesting that individuals with the greatest urgency to change unhealthy behaviours are often the most motivated (Boyle, et al., 1998; Keenan, 2009). Thus, the diagnosis of an acute or chronic condition could provide health professionals with the opportunity to intervene upon unhealthy lifestyle behaviours (Keenan, 2009). This potential strategy could prove to be most effective among older and disadvantaged individuals as they represent a segment of the population who are more prone to chronic conditions. The identification of demographic, cognitive-behavioural, and social determinants that distinguish between individuals who choose to adopt and/or maintain health behaviours and their counterparts who do not adopt healthy behaviours requires further evaluation (Boniface, et al., 2001; Boyle, et al., 1998; Nigg, et al., 2002; O'Hea, Wood, & Brantley, 2003). This would assist public health professionals in effectively allocating resources (Boniface, et al., 2001; Boyle, et al., 1998).

Although it was established that individuals have the capacity to achieve behavioural changes, it is unknown whether such changes had transpired in a simultaneous or sequential fashion. The manner in which multiple behavioural changes are administered continues to be a top priority among health professionals and requires further attention (Nigg, et al., 2002; Orleans, 2005; Ory, et al., 2002; Pronk, Peek, et al., 2004; Spring, Moller, & Coons, 2012; Sweet & Fortier, 2010). Simultaneous behaviour change has often drawn criticism for overwhelming individuals and possibly hindering behavioural change (Berg, et al., 2012). However, some have argued that this may not be the case and have reported results that are in favour of using a simultaneous approach in achieving behavioural change (Hyman, et al., 2007; J. J. Prochaska, et al., 2006). Others have suggested that a sequential approach could prove to be more effective in adopting and

maintaining multiple behavioural changes (Spring, et al., 2004). In one instance, Vandelanotte et al. (2008) observed that both simultaneous and sequential approaches demonstrated similar success in multiple behavioural changes. If individuals are to be successful in adopting and maintaining multiple behavioural changes, research must determine an appropriate method of administering behavioural changes that does not overwhelm individuals and allows them to take advantage of available resources.

If a sequential approach is deemed appropriate for multiple health behavioural changes, an additional concern for health professionals arises in the form of causality (Orleans, 2005). In other words, do changes in smoking behaviour produce changes in physical activity or do changes in physical activity result in changes in smoking behaviour? In the case of physical activity and dietary fat intake, Vandelanotte et al. (2008) observed that the order in which behavioural changes were initially administered had no influence on the success of achieving changes in both behaviours. However, can similar conclusions be drawn for other health behaviours such as alcohol consumption and smoking? The order in which behavioural changes occurred was not a focal point of this study as causality could not be determined through correlations. A randomized study design would be appropriate for establishing causality between health behaviours. This could be an avenue for future research to pursue. If the success of multiple health behaviour interventions does not appear to be dependent upon the order in which behaviours are administered, it could be meaningful to evaluate whether a choice-based intervention provides greater success in changing multiple behaviours (Vandelanotte, et al., 2008).

Previous literature suggests that the presence of multiple unhealthy behaviours are associated with specific demographic characteristics; male, a young age, and lower levels of education and income (Berrigan, et al., 2003; Fine, et al., 2004; Laaksonen, et al., 2003; Li, et al., 2009; Prattala, et al., 1994; Rosal, et al., 2001). As the probability of possessing multiple unhealthy behaviours is greater among specific segments of the general population, it appears that these individuals would benefit greatly from multiple behavioural changes. Future research should determine whether the findings of this study are consistent among various gender, age, educational, and socioeconomic groups (Pronk, Peek, et al., 2004). Notwithstanding the role that demographic variables may have on behavioural change, cognitive-behavioural characteristics should not be ignored. It is

conceivable that co-variation is more likely among individuals with higher levels of mastery, self-efficacy, and/or motivational readiness to adopt healthier behaviours. Unfortunately, information pertaining to cognitive-behavioural characteristics are not typically addressed nor requested in large population-based health surveys. If findings among various subgroups of the population are inconsistent, this would be an indication that health professionals need to tailor public health programs, strategies, and policies towards specific subgroups of the general population.

The mediation model involving alcohol consumption and physical activity revealed an interesting relationship between these two behaviours. Alcohol consumption had a positive influence on perceived mastery which in succession had a significant positive effect on leisure-time physical activity. It was speculated that an increase in alcohol consumption may provide individuals with a false sense of control that inadvertently leads to a rise in leisure-time physical activity levels. However, this theory has yet to be confirmed and requires further investigation into the interpretation of this relationship.

Chapter 6
Conclusion

6.1 Summary:

While multiple health behaviour change may represent the future of disease prevention (L. Gordon, et al., 2007; J. O. Prochaska, 2008) several questions continue to persist, most notably, do changes in one health behaviour influence changes in additional behaviours (Butterfield, et al., 2004; Clark, et al., 2005; Costakis, et al., 1999; S. A. French, et al., 1996; Herrick, et al., 1997; Rosal, et al., 2001)? This study attempted to evaluate the interrelationship between multiple behavioural changes by incorporating a longitudinal study design across multiple data collection cycles in a nationally representative sample. Significant co-variation between health behaviours was observed for leisure-time physical activity energy expenditure and smoking as well as alcohol consumption and smoking. In both cases, these relationships suggested the occurrence of a gateway behaviour wherein a favourable change in one behaviour was associated with a positive change in the other. Unfortunately, these associations also implied that negative behavioural changes facilitate unfavourable changes in an additional behaviour. One should interpret these findings with caution as the correlations between behavioural changes were weak and statistical significance could be attributed to the substantial sample size of this secondary analysis. However, it can be argued that these weak correlations have the potential to substantially influence the health and well-being of thousands of individuals within the general population. It is important to consider that co-variation between behaviours occurred in a natural environment, most likely without the assistance of health professionals or interventions. The implementation of an intervention may have resulted in stronger correlations between behavioural changes. Nevertheless the findings of this study were exploratory and intended to guide the development of tailored multiple behavioural interventions.

The second objective, another focal point in multiple health behaviour change research (Nigg, et al., 2002; Rosal, et al., 2001), was to evaluate the potential mediating effect of mastery in the interrelationship of behavioural changes. While mastery was significantly associated with individual behaviours including leisure-time physical activity energy

expenditure and alcohol consumption, it was predominantly unsuccessful in mediating the interrelationship of behavioural changes. The only exception in which mastery mediated the interrelationship between multiple behavioural changes was observed between alcohol consumption and leisure-time physical activity. In this case, increases in alcohol consumption resulted in an enhancement of one's perceived control which consequently brought about a rise in leisure-time physical activity. Therefore, public health programs which attempt to assist individuals in achieving moderation and/or abstinence from the consumption of alcohol may inadvertently influence leisure-time physical activity levels in a negative manner. Health professionals are unlikely to endorse this notion as alternative forms of treatment for alcohol consumption exists that do not compromise additional health behaviours. Future research will be required to evaluate the mediation effect of additional cognitive-behavioural mechanisms between behavioural changes (J. J. Prochaska & Prochaska, 2011; Sweet & Fortier, 2010).

Although the majority of behavioural change research has concentrated on single behavioural change (Berg, et al., 2012; Costakis, et al., 1999; Coups, et al., 2004; Emmons, et al., 1994; Nigg & Long, 2012; Pronk, Peek, et al., 2004), health professionals are beginning to realize that multiple health behaviour change has the potential to significantly impact the health and well-being of the general population by effectively utilizing and allocating time, effort, and resources, while minimizing the strain on the health care system, workers compensation costs, and workplace absenteeism (Edington, 2001; J. J. Prochaska, Spring, et al., 2008; J. J. Prochaska, Velicer, et al., 2008; Pronk, Peek, et al., 2004). However, if multiple health behavioural programs are to be effective, a collaborative approach that considers the opinions and views of researchers, primary care physicians, policy makers, health promotion professionals, counsellors, individuals, and populations will be necessary (J. J. Prochaska, Velicer, et al., 2008). The integration of pharmacological treatment, education, legislation and policies, incentives, and prevention programs will also be essential in promoting behavioural changes (S. Solomon & Kington, 2002; S. D. Solomon, 2005). Furthermore, it is essential for individuals to establish realistic and attainable behavioural aspirations, monitor their progress on a consistent basis, and integrate oneself with positive and encouraging social support that promotes the adoption of such healthy behaviours as well

as enhances adherence to public health programs (Ory, et al., 2002). The development and implementation of such interventions is long overdue.

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Appendix 1: Covariances and Correlations Between Latent Variables

	Covariance	Correlation
Alcohol Consumption (n = 15,167):		
Alcohol Consumption Intercept & Alcohol Consumption Slope	-0.02 *	-0.22
Physical Activity (n = 15,167):		
Physical Activity Intercept & Physical Activity Slope	-0.17 *	-0.50
Smoking (n = 15,167):		
Smoking Intercept & Smoking Slope	-6.43 *	-0.67
Alcohol Consumption and Physical Activity (n = 15,167):		
Alcohol Consumption Intercept & Alcohol Consumption Slope	-0.02 *	-0.22
Physical Activity Intercept & Physical Activity Slope	-0.17 *	-0.50
Alcohol Consumption Intercept & Physical Activity Intercept	0.06 *	0.06
Alcohol Consumption Intercept & Physical Activity Slope	-0.04×10^{-1}	-0.03
Alcohol Consumption Slope & Physical Activity Intercept	0.02 *	0.10
Alcohol Consumption Slope & Physical Activity Slope	†	0.01
Physical Activity and Smoking (n = 15,167):		
Physical Activity Intercept & Physical Activity Slope	-0.17 *	-0.50
Smoking Intercept & Smoking Slope	-6.43 *	-0.67
Physical Activity Intercept & Smoking Intercept	-1.52 *	-0.12
Physical Activity Intercept & Smoking Slope	0.27 *	0.16
Physical Activity Slope & Smoking Intercept	0.03	0.02
Physical Activity Slope & Smoking Slope	-0.03 *	-0.12
Alcohol Consumption and Smoking (n = 15,167):		
Alcohol Consumption Intercept & Alcohol Consumption Slope	-0.02 *	-0.22
Smoking Intercept & Smoking Slope	-6.43 *	-0.67
Alcohol Consumption Intercept & Smoking Intercept	1.41 *	0.24
Alcohol Consumption Intercept & Smoking Slope	-0.09 *	-0.12
Alcohol Consumption Slope & Smoking Intercept	-0.03	-0.03
Alcohol Consumption Slope & Smoking Slope	0.02 *	0.15

* Significant at $p \leq 0.01$.

† Parameter estimate was < 0.001.