Contribution of Exergaming Behaviour to Physical Activity:

Toward Better Understanding the Role of Motivation

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ABSTRACT

Contribution of Exergaming Behaviour to Physical Activity: Toward Better Understanding the Role of Motivation

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Physical activity (PA) is associated with numerous health benefits. Because PA patterns established early in life track into adulthood, it is important that children develop and sustain healthy PA habits. Current guidelines recommend that youth accumulate ≥ 60 minutes of moderate to vigorous intensity PA daily, but many youth do not attain this level. Evaluation of public health interventions that aim to promote PA provide little evidence of sustained positive effects over time. This could relate, at least in part, to interventions lacking a strong conceptual foundation and, in particular, to a lack of underpinnings that recognize the central role of motivation in PA. It is important that effective strategies to increase and sustain healthy PA levels in youth are identified. The Self-Determination Theory is used to explain why people adopt and maintain healthy PA behaviors and posits that sustained PA relates to natural or intrinsic tendencies or motivations to behave in healthy and effective ways. Positive PA experiences in school, at home and in community settings may foster an internal desire or motivation to sustain PA participation simply for its challenges or for enjoyment. Lack of sustained PA among youth could reflect a scarcity of enjoyable PA options that fit with the sophisticated technetronic expectations of youth today. PA interventions must "keep up with the times," by acknowledging young peoples' prevailing interests and by incorporating advancements in technology that heighten interest and motivation for PA.

Exergaming, a type of non-sedentary videogame that requires players to be physically active in order to attain a series of incrementally challenging goals, is increasingly viewed as an enjoyable PA option among today's technology-immersed youth. However, although critical to informing the design, implementation and sustainability of exergaming interventions, evidence on exergaming-related motivation, preferences, intentions and sustainability is lacking. Research in this domain is needed to ascertain whether exergaming interventions can help youth become

and remain physically active, and which facets of exergaming hold the most promise in sustaining positive PA change. More specifically, using "gamified augmented reality" such as exergaming could help youth attain recommended PA levels and promote sustainable healthy behaviour, while at the same time contributing to enjoyment of PA.

The three studies described in this thesis examine motivation and exergaming in-depth using SDT and its tenants as a theoretical guide and a common theme across studies. Thus, the role of motivation and intentions in exergaming behaviour and how they contribute to PA in the general population of youth is a key contribution of this dissertation.

Study 1, a review of reviews on exergaming, provides background for the next two studies, each of which was conducted in population-based (as opposed to clinical or experimental) settings. Twenty-five reviews spanning 2009 to 2016 were retained, each of which incorporated between 5 and 100 articles. A positive relationship between exergaming and energy expenditure (EE) was well-documented, but whether exergaming increases PA or changes body composition was not established. There is however, evidence that exergaming (i.e., as a non-sedentary use of screens) is a healthy alternative to sedentary behaviour, that it improves cognitive function, that it is an interesting and enjoyable pastime in youth, that it shows promise as a PA option by adding variety and alternative PA forms in health and dietary interventions and finally that it is likely more health-promoting than traditional videogames because of higher EE and possibly improved physical fitness, body composition and cognitive health. However, more research and specifically, longitudinal studies are needed to assess whether exergaming can be sustained to obtain these benefits over time.

Study 2 identified correlates of sustained exergaming. We reported that almost 50% of grade 9 students sustained exergaming for 2-3 years. Study results suggest that in non-clinical settings, exergaming may be a practical approach to help adolescents maintain PA during adolescence.

Study 3 examined the psychometric properties of a new scale to assess reasons for exergaming (i.e., the Reasons to Exergame (RTEX) scale). This study also examined whether and how the scale relates to the timing, intensity and duration of past-month exergaming. RTEX items were developed in consultation with PA and exergaming experts and using key exergaming constructs, including PA, general interest in videogames and enjoyment of

exergaming. RTEX was found to be a reliable and valid assessment of reasons to exergame. However, further studies should replicate these initial findings in larger, more diverse samples.

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CONTRIBUTIONS OF AUTHORS

This dissertation comprises three research papers, two of which used data collected in the longitudinal Nicotine Dependence in Teens and AdoQuest studies. As an undergraduate and Master's student, I assisted with data collection in both the Nicotine Dependence in Teens and AdoQuest studies. As a Doctoral student, I helped incorporate new material on exergaming into both studies. Finally, in collaboration with my PhD supervisors, Dr. Tracie Barnett and Dr. Lisa Kakinami, I conducted all statistical analyses and prepared the manuscripts included herein for submission. Funding for the NDIT study was provided by the Canadian Cancer Society. Funding for the AdoQuest study was provided by the Canadian Tobacco Control Research Initiative and the Institut national de santé publique du Québec. During my PhD training, I was supported by a Doctoral Fellowship from the Fonds de Recherche du Québec – Santé, a Canadian Institutes of Health Research Training Grant in Population Intervention for Chronic Disease Prevention: A Pan- Canadian Program and a Bourse de la Fondation CHU Sainte-Justine. I declare that I am the sole author of the entire dissertation document.

Table of Contents

List of Figures

List of Tables

List of Appendices

CHAPTER 1

INTRODUCTION

1.1 General Introduction

It is well-established that physical activity (PA) is associated with numerous health benefits,[1,2] and that PA patterns established early in life track into adulthood.[3,4] Current recommendations are that youth ages 5-18 years accumulate 60 minutes or more of moderate to vigorous intensity PA daily.[5] However, about 60% of Canadian children and youth aged 5 to 17 failed to meet the recommended targets for PA in 2016-17.[6] Reasons include low participation levels in active transportation, elimination or reductions in school physical education and organized sports programs,[7] and the widespread preference among youth to engage in sedentary behaviours such as TV-viewing, computer use or videogames during their leisure time.[8,9] Lack of motivation, interest and intention to participate in PA also contribute to low PA levels, among other factors (see Appendix A for other possible factors). Despite public health efforts to increase PA among youth, the prevalence of PA participation in the general population has remained low for at least a decade - only 27% of boys and 18% of girls attained recommended levels in 2002, and the percents were nearly identical in 2010 at 28% and 18% in boys and girls, respectively.[10]

Youth spend between 2 to 4.5 hours per day on screen media.[11] Similar to TV-viewing, videogames are typically sedentary such that little energy is expended while playing. However, the gaming world has been revolutionized by the introduction of exergaming consoles such as Nintendo Wii Sports, Xbox Kinect and PlayStation EyeToy. These gaming consoles provide players with the opportunity to play videogames actively because they require part- or whole-body movement.[12] Consoles use input devices such as accelerometers, gyroscopes, vision-based devices, ergometers (i.e., exercise equipment), pressure and touch sensors (i.e., pads and mats) and special purpose devices to detect and process the player's movements during the game and to interact with the player.[13] Exergaming is viewed by many as a viable and promising method to increase PA among today's "technology-immersed" youth.[14,15] For example, if frequent users of sedentary videogames replaced this time with exergaming, weekly energy expenditure (EE) would increase by an average of 4.5% a week.[16]

Exergames include interactive aerobic fitness games, dance simulation games, interactive cycling games, isometric resistance games and sports simulation games.[17] Popularity of specific games may be sex-specific, whereby girls prefer dance games, and boys prefer combat or sports games.[18] Mobile exergaming (i.e., exergaming using a mobile phone or portable screen) and augmented reality (i.e., a technology that superimposes a virtual image on the user's view of the real world) are increasing the popularity of exergaming by using gamification principles (i.e., using game-design elements and game principles in non-game contexts) and because of the appeal of the online social network capability and compatibility with smartphones.[19,20] With mobile exergaming, the real world can become the 'game map' or playground, and players can discover and learn about new places while obtaining health benefits through movement.[19,20] Mobile exergaming is increasing in popularity with the release of games like Pokémon Go and Zombie Run!.[21,22] Exergaming equipment and systems such as multiplayer Dance Dance Revolution Systems, Reax lights, Reax training, exergame floor wall systems such as Interactive Touch Wall are also increasingly available in community centers, schools and gyms. These exergaming projections can turn any area into a virtual indoor playground that allows players to interact with graphics and sounds projected onto the floor or wall.

Studies of exergaming have been undertaken primarily within the health sector, and in particular, within public health, clinical, laboratory and rehabilitation settings. Other disciplines such as psychology, sport science, neuroscience and computer science have also begun to incorporate exergaming into research and together, examine exergaming from a variety of different perspectives.[23-27]

Despite burgeoning interest and although exergaming emerged on the market over 20 years ago, research on exergaming is in its infancy. This PhD dissertation, which includes three research studies, begins by synthesizing existing research and focusing on recommendations from the past 20 years for future exergaming research. Specifically, Study 1 is a review of reviews on exergaming, in which the available empirical evidence on exergaming is summarized, providing relevant background information for the next two studies. Study 2 identifies predictors and correlates of sustained exergaming on the premise that longer-term participation in exergaming leads to greater health benefits. The role of PA motivation is examined specifically given that motivation is a critical factor in supporting sustained PA, which in turn is associated with important health outcomes. Study 3 examines the psychometric properties of a new scale

developed by the candidate that was designed to measure reasons to exergame. Once validated, this scale could be used in research to investigate different facets of motivation to exergame in specific population subgroups. Both Study 2 and Study 3 were conducted in population-based settings, which help bring exergaming research "out of the laboratory" and into "the real world".

The next section overviews the literature on exergaming, beginning with a description of exergaming and its health and other benefits. Following, exergaming-related concepts, including enjoyment, motivation and barriers, are presented. Finally, measurement of exergaming in the context of research is described.

1.2 Overview of Exergaming

Exergames are interactive media tools designed primarily for entertainment, although they have also been labelled as "serious games" because they enhance communication, educate, improve exercise practices, rehabilitate users, and provide useful learning experiences.[28-31] This "learner-centered" experience is enjoyable to many youth, it can foster positive activity behaviours[32], and it is viewed by some researchers and practitioners as a viable approach to increase PA.[28-31] See Appendix B for an in-depth description of variables important to the exergaming experience.

1.2.1 Prevalence of exergaming

In 2009, 36% of youth ages 8-18 years had Wii game consoles (an exergaming console) at home.[33] The weekly prevalence of exergaming ranges from 18-43%.[18,34-36] O'Loughlin et al. (2012)[18] reported that exergamers played 2 days per week for 50 minutes on average and that 73% of exergamers played at a self-reported moderate or vigorous intensity. Results from a U.S. national survey in 2010 indicated that 40% of high school students exergamed at least 1 day per week,[36] and Kakinami et al. in 2014[34] reported that 18% of young adults had exergamed in the past 30 days. In addition, in 2014, a representative sample of 20,122 Canadian youth in grades 6-10 reported exergaming an average of 30 minutes per day.[37] Because the prevalence of exergaming may be as high as 43%, there is considerable interest in the potential health benefits of exergaming in youth.

1.2.2 Exergaming as a PA alternative

Much of todays youth fail to meet daily PA recommendations (about 40% of Canadian children and youth aged 5 to 17 years meet the recommended targets for PA in 2016-17).[6] Many youth report negative experiences in sport-related activities[38] or in physical education classes[39] including lack of fun, parental pressure,[38] body image issues,[40] peer judgement and ridicule,[38,40] too much emphasis on competition,[38] fear of making mistakes, lack of competence,[40] stress[41] and lack of time.[40] These negative experiences may be more common in girls.[40,42,43] Youth who report negative experiences with traditional types of PA usually report lower PA levels.[44] Thus, because not all youth are interested in traditional sports (i.e., about 43.4% of youth ages 5-18 years do not play traditional sports)[45] or recreational activity, innovative approaches such as exergaming as alternatives to traditional sports and recreational activities are needed.[46] In addition, exergaming can be added to existing activities to further increase PA, even among those who enjoy and play sports regularly. Exergaming may be an excellent PA option for these youth since they are fun; they can be played alone, online or with friends or family; they can be enjoyed regardless of weigh status;[12] they allow setting personal game level challenges, goals, and competition levels; they provide feedback that is important for progress; they foster PA competence and motivation, and they may appeal to those not intrinsically motivated to exercise.[47] Recent research suggests that exergaming during bouts of high intensity interval training can increase enjoyment of the activity.[48] Further, given that enjoyment predicts adherence to exercise, exergaming may be effective in promoting adherence to high intensity interval training in the general population.[48] Other recent research among college students suggests that, although non-exergaming treadmill running expended more energy, exergaming may lead to lower perceived fatigue and potentially higher effort and enjoyment compared to traditional exercise.[48] Thus, exergaming adds to the existing range of opportunities for PA for youth regardless of whether they already engage in other types of PA. This current dissertation studies the tenet that exergaming may help all youth increase PA levels, including those who are not interested in traditional types of PA and those who are already active.[10] In addition to possibly increasing PA, exergaming may also decrease sedentary behaviour (i.e., this is considered to be separate and distinct from physical inactivity and defined as any behavior with an energy expenditure ≤1.5 metabolic equivalents, while in a sitting, reclining or lying posture),[50] by replacing sedentary screen time with more active screen-based pursuits.[51]

Exergaming has broad appeal[52] because of its adaptability to all skill levels, self-learning tutorials, autonomous playing schedules, the ability to play with or without others, the individualized nature of the games, the option to engage in competitive or non-competitive games, real-time feedback, and independence from coaching. Many youth spend more than 50 hours per week in front of screens (i.e., videogames, cell phones, computers, TV-viewing) with 'gaming' being one of the most popular forms of screen entertainment.[53] With the availability of better graphics and new videogames with mobile and tablet applications (i.e., APPs), gaming continues to grow in popularity, as illustrated by *Pokémon Go*.[21,54]

Exergames can be played in a variety of settings thereby increasing opportunities for youth to be active while removing common barriers to PA such as lack of time, fear of failure and safety issues, among others.[28-31] For example, youth can exergame at home or at school, thus addressing concerns about neighbourhood safety. A recent study on the preferences of Canadian families that exergame (i.e., defined as at least one parent exergaming with their child at least once every two weeks for 30 minutes on average in the past month) concluded that exergaming is an option for engaging in PA with other family members and could be considered as one activity among others that encompass a program for the family, especially during bad weather and on weekends.[55] Since exergames can be played on mobile phones and tablets using APPs such as *Pokémon Go* they are widely accessible.[56,57] In addition, many schools are incorporating exergaming into their PA programs.[58,93] Exergaming may be particularly attractive to youth who already engage in screen time and videogames.[56,59]

1.2.3 Health benefits of exergaming

Exergaming has many of the same advantages for health as traditional modes of PA, including a variety of physical, mental, cognitive and social benefits.[15,30] Some benefits may arise through increases in PA levels, although not all PA benefits (i.e., its impact on cardiovascular disease in adults) have been studied in relation to exergaming. Three of the main potential benefits of exergames include increased EE,[60-62] development of fundamental motor skills[12,46,63] and increased motivation to participate in PA.[64,65]

One of the most important health benefits of increased PA may be the reduction or stabilization in weight and weight-related consequences.[66] Incorporating exergaming into a PA regimen could decrease adiposity because it motivates and strengthens PA habits in ways that are

enjoyable and purposeful.[67] Although reductions in Body mass index (BMI) are not always observed,[68] several studies[69-72] do report that exergaming decreases BMI. For example, among 54 overweight and obese African-American adolescents participating in a 20-week exergaming intervention, those in the exergaming group lost more weight than control participants (M weight loss = 1.65 kg; SD = 4.52) than the control group (which did not lose weight).[71] However, it is arguable even if exergaming does not always elicit reductions in BMI, there are numerous other health benefits of increasing PA and that the focus on BMI is a limited perspective.[73]

Based on evidence from a small number of studies, exergaming decreases sedentary behaviour.[74,75] Goa et al. (2014)[76] found that introducing exergames into schools reduced sedentary behaviour among pre-adolescent youth. A possible corollary is that, by replacing time spent in non-active videogames (or inactive screen time), exergaming capitalizes on the attraction to gaming (and screens) and therefore transforms screen time into a more physically active pastime.[51,61] In a sample of 60 children, Maloney et al. (2008)[77] reported that those participating in a 28-week exergaming intervention decreased the duration of sedentary screen time over 60 minutes per week,[77] and Easton et al. (2013)[78] reported that exergaming decreased sedentary behaviour time in 20 college students in the pre-post intervention period (463 ± 125 min/day vs. 391 ± 126 min/day, respectively; $P<0.001$).[78] Exergaming may also help prevent expected increases in sedentary behaviour as children age. Norman et al.(2013)[79,80] observed that increases in PA were achieved in a 4-week exergaming intervention for adolescents and in addition, sedentary levels remained stable (did not increase) over the intervention period.[80] Lanningham-Foster et al. (2006)[61] reported that EE more than doubled when sedentary screen time was converted to active screen time.[61] Almost all exergames increase EE over traditional videogames,[81] even if exergaming elicits only light PA. Taking breaks from sedentary behaviour may also be promoted through exergame play.[76,82]

In addition to physical health benefits, exergaming has mental health benefits.[24] In a review of nine studies examining the effects of exergaming on depression, Jinhui et al. (2016)[24] concluded that exergaming improves mental health by alleviating depression symptoms.[24] Exergaming may also increase executive functioning in youth[15] and improve rehabilitation in select populations.[83]

1.2.4 Enjoyment

The importance of enjoyment is gaining more attention in exergaming research because it may be key to sustaining a higher and/or sustained PA level.[84] Moreover, greater enjoyment in PA has cognitive benefits, which in turn may positively influence academic achievement.[85] Numerous psychosocial, physiological and embodiment characteristics are associated with having fun or reporting enjoyment playing videogames and exergames. For example, exergaming increases positive mood after just a single bout during a school physical education class.[86] However, the enjoyment experience appears to be individual, and research suggests that this may relate to different combinations of game design features.[87]

Simons et al. (2011),[51] in a study of 37 youth, reported that aspects that made videogames enjoyable included genre, interesting and realistic storylines, competition, group play, feelings of mastery, challenges, doing things that are not possible in real life, high-quality graphics, realistic graphics and the feeling of really being in the game.[51] In comparison to traditional videogames, participants enjoyed specific aspects of exergaming such as being physically active, interactivity, realistic movements, one-to-one translation of movements into the game and the social aspects. Young adolescents especially liked that they could exergame with others (which can be done virtually or in person) and that the 'gaming' aspects were less serious than in non-active videogames. In addition to the gaming experience and in contrast to traditional videogames, exergamers experienced positive feelings related to PA.

1.2.5 Factors associated with exergaming

Research on factors associated with exergaming in naturalistic settings is limited. O'Loughlin et al. (2012)[18] observed that exergamers were more likely to be girls, to play non-active videogames, to watch TV ≥ 2 hours per day, to report weight-related stress, and to be non-smokers. Dutch adolescents with lower levels of education were more likely to exergame >1 hour per week than those in enriched education programs, and among those who play videogames and exergames, boys and older adolescents were less likely to exergame than girls.[88] Simons et al. (2014)[35] found no significant differences between regular and non-regular exergamers by sex, education level of adolescents or parents, ethnicity or sedentary behaviour.[35]

More recent research by Barr-Anderson et al. (2018)[89] observed that among 2700 diverse youth ranging in age from 12 to 17 years, male and female exergamers were more likely to be

younger and black and that exergamers did not report significantly more PA than non-exergamers with the exception of female exergamers, who engaged in more vigorous PA than their non-exergaming counterparts.[89] Finally, Rhoads et al. (2018)[55] examined the correlates of family exergaming and reported that parents of young exergamers preferred to play sports and dance exergames with their children on weekends (rather than weekdays) and during inclement weather. Family exergame playtime was associated with tenants of the Theory of Planned Behaviour (a theory that posits that behaviors are determined by intentions, which in turn are determined by three factors: attitude toward the behavior, subjective norms, and perceived behavioral control)[90] including intentions, affective and instrumental attitudes, and descriptive norms. TV-viewing was reported as the most common activity that exergames displace.[55]

Overall, an examination of the correlates of exergaming suggest that preferences for exergaming among young women and female adolescents compared to older female and their male counterparts.[18] Although female exergamers appear to increase their moderate to vigorous intensity PA through exergaming,[34] differences in PA level between exergamers and non-exergamers are negligible. Longitudinal studies are needed to better assess whether exergaming increases PA, decreases sedentary behaviour and enjoyment is likely key in motivating young people to exergame and to continue exergaming.[91,92] Peng et al. (2011)[62] suggested that enjoyment and intrinsic motivation play a pivotal role in outcomes such as time spent or intensity of exergaming.[62] However, we do not yet fully understand why youth choose to exergame over traditional videogames. Factors such as exergame context (i.e., group vs. individual), body part used (i.e., whole body, upper or lower body, upper or lower limbs), cooperative vs. competitive play, and type of console or device used likely relate to player motivation but have not yet been fully elucidated (see Appendix B for variables related to exergaming motivation).

1.2.7 Measurement of exergaming

In research, participation in exergaming is usually measured in self-report questionnaires or using an external device such as accelerometers, indirect calorimetry or heart rate monitoring. Timing, intensity and frequency of exergaming may also be measured by feedback from exergaming consoles or using self-report questionnaires (e.g., rate of perceived exertion during an exergaming bout, often using the BORG perceived exertion scale).[93] The outcome of interest

in exergaming studies, at least in controlled laboratory studies and randomized controlled trials (RCTs), is often EE, which is usually measured in a single or a few exergaming bouts on a single day.

Exergaming measured in self-report questionnaires typically comprises asking participants about the number of bouts of exergaming over a specified time-period (i.e., previous week, previous month, previous year), the total number of minutes exergaming per bout and whether the exergames were played at light, moderate or vigorous intensity. Although there are scales that measure exergaming motivation after an acute bout of playing,[79] there are currently no widely accepted valid and reliable self-report scales to measure exergaming behaviour (frequency, timing and intensity) in naturalistic settings.[93] Given the popularity of exergaming, monitoring trends in exergaming behaviour should be incorporated into PA surveillance.

1.3 Theoretical/Conceptual Framework

1.3.1 Self-Determination Theory (SDT)

SDT is a general theory of human motivation (also referred to as "behaviour regulation") that concerns the choices that people make freely without external influences or interference. It describes motivational states along a self-determination continuum,[94,95] focusing on the degree to which an individual's behaviour is self-endorsed and self-determined.[96-98] SDT has evolved over the past three decades into several "micro-theories," and the research presented in this dissertation focuses on one such micro-theory. The Organismic Integration Theory (see Appendix C) explains how a person is motivated towards internalizing a behaviour (such as PA). The SDT and the Organismic Integration Theory provide a framework that underpins the three manuscripts that comprise this dissertation.

1.3.2 Definition of concepts

The Organismic Integration Theory speculates that there are three primary states of motivation which are measured by the degree to which an activity is self-determined, including amotivated (i.e., not self-determined), extrinsically motivated (i.e., partially self-determined) and intrinsically motivated (i.e., entirely self-determined). Individuals do not automatically progress through these states until a behaviour becomes internalized and may not always remain in one state. They may cycle in and out of different states as motivation shifts.[99] For example, behaviour

regulation might change with age or life circumstances (i.e., weight gain, desire to be in shape) or though intervention or external reasons such as pressure from a loved one. Behaviour regulation may also be stable over time.[100] Appendix C illustrates the Organismic Integration Theory[94] and describes each regulation. The SDT suggests that if an activity satisfies the three core psychological needs of autonomy, competence and relatedness, individuals will be more likely to be intrinsically motivated. For example, an individual will engage in PA if he/she makes a choice to do so (i.e., reflecting autonomy), they feel they are gaining valuable skills or achieving a goal (i.e., reflecting competence) or they enjoy the social interactions (i.e., reflecting relatedness).[94,98,99,101-104] Exergaming has the potential to satisfy the three core needs as stipulated by the SDT, thereby promoting intrinsic motivation. For instance, when exergaming, the individual chooses which game to play, and at what level, they develop their own characters and avatars (i.e., autonomy), they continually improves their skills and gains points, rewards and prestige (i.e., competence) and they have the option to play with others or share progress on social media (i.e., relatedness).[105]

1.3.3 Organismic Integration Theory and PA

The Organismic Integration Theory, through SDT tenants, has been used to explain why people adopt and maintain healthy behaviours,[96,98,106] such as exercise and PA participation.[96,98,106] Self-determined motivation is considered important in understanding behavioural variation in PA. For example, increased time, intensity and enjoyment of PA are associated with intrinsic exercise regulation[107-109] as well as health, optimal functioning, quality of life, fun, skill improvement, personal accomplishment and excitement while engaging in PA. Self-determined motivation relates to persistence at a task, psychological health and improved well-being.[94]

Although PA initiation may arise from external reasons to become active (ex. lose weight, pressure from your partner), those with higher intrinsic regulation report increased intentions to engage in more PA compared to those with external PA regulations and this relationship is observed regardless of age group (e.g.[107,108,110,111]) and a focus on internalizing PA is warranted for sustaining the activity. Studies support that extrinsic and amotivated regulations are associated with lower PA levels.[101,104] Reports have even established the long term effects of

PA intervention using the SDT, whereby even after 24 months, participants with autonomous regulations report higher PA levels.[101]

1.3.4 Measuring behaviour regulation using Organismic Integration Theory

The Behavioural Regulation in Exercise Questionnaire (BREQ-2)[112] measures behaviour regulation in exercise. There are three BREQ versions to date; this research uses BREQ-2, which includes 19 items that incorporate 5 sub-scales from least to most self-determined: amotivation, external regulation, introjected regulation, identified regulation and intrinsic regulation (see Appendix C). Participants respond to each item on a 5-point Likert scale ranging from 0 (not true for me) to 4 (very true for me). The multidimensional structure of BREQ-2 (i.e., incorporating amotivation, external regulation, introjected regulation, identified regulation and intrinsic regulation) has been confirmed,[113] and each subscale (i.e. each motive) demonstrates internal consistency (α=0.73-0.86).[107,108,110,113,114] Behavioural regulations can be assessed with the BREQ-2 using the Relative Autonomy Index (i.e., a score using all the regulations) as a composite score or by using each type of regulation individually (i.e. each subscale separately). Results from previous studies show consistent support for a positive relationship between autonomous behaviour regulation and exercise behaviour, using single regulations, summary measures or the Relative Autonomy Index.[104] This dissertation measures the BREQ-2 using the subscales and not the Relative Autonomy Index.

1.3.5 Exergaming and behaviour regulation

Exergame play may increase intrinsic motivation and self-efficacy (an individual's belief in their capacity to execute a behavior to obtain their goals), which are on the pathway to behaviour change and thereby support the potential of exergaming to promote PA.[84] The link between behaviour regulation and exergaming has been studied in clinical settings and in specific populations such as overweight youth,[115,116] but this association has not been well investigated in population-based samples of youth using the Organismic Integration Theory.[93] It is unclear whether exercise behaviour regulation differs between exergamers and non-exergamers or between those who do and do not sustain exergaming. In a cross-sectional study, girls who exergamed scored higher on external regulations than non-exergamers.[117] Exergame intensity and achieving PA guidelines were associated with identified regulation, while time

spent exergaming per week was positively associated with amotivation. These results indicated that girls who are not motivated for traditional PA spend more time exergaming. In boys who exergamed, intrinsic regulation was associated with exergaming duration. Although not using the Organismic Integration Theory specifically and conducted in a clinical setting, Staino et al. (2012)[118] observed that playing cooperative exergames elicited higher intrinsic motivation than competitive exergames and that intrinsic motivation was related to higher EE while exergaming.[118] Using the BREQ in a clinical setting, Osorio et al. (2012)[116] observed that intrinsic and identified regulation were higher among adult exergamers compared to non-exergamers and suggested that enjoyment and perceptions of feeling better physically and mentally increased motivation to play and promoted broader emotional experiences during exergaming. As the popularity of exergaming grows, increased understanding of the association between PA behaviour regulation and exergaming may inform the development of interventions for youth that support sustained exergaming.[116] Although, it is not currently clear which game characteristics increases motivation and enjoyment, it may also be important to study in order to achieve certain PA levels when using the right exergame.[87]

1.3.6 Limitations of previous research

Findings from exergaming research suggest promising effects on PA levels in youth.[15,30,31] In a recent review of 27 studies, most exergames met American College of Sports Medicine guidelines for health and fitness PA intensity levels, and exergaming increased EE up to 300% above resting levels.[31] However, most of the studies included in the review were cross-sectional and laboratory-based. Few population-based studies have assessed whether exergaming is sustainable in real-life settings, the characteristics of individuals who are more likely to sustain exergaming and whether motivation, intentions or preferences determine sustained exergaming.[15,29,31,119] In general, evaluation of public health interventions to increase PA provide little evidence of sustainability of positive effects (i.e., increased PA) over time, especially when the intervention is no longer available.[120,121] This may relate to less emphasis on PA motivation using well-established PA motivation theories (i.e., SDT), or alternatively to a lack of enjoyable PA options that fit well in today's technetronic society where advances have reduced the need to be physically active (ex. TV remote). PA interventions should be designed such that young

peoples' prevailing interests are respected; one such approach may be to incorporate advancements in technology that heighten interest and motivation for PA.[14,122]

While PA motivation has been well-studied with respect to traditional forms of PA, it has not been fully investigated in exergaming, wherein it may relate to either the PA and/or to the "gaming" aspects of exergaming. Numerous calls have been made for researchers to identify factors associated with youth motivation to sustain PA participation, and in regard to this current research, to factors associated with motivation and sustaining exergaming.[123-125] In addition, calls have been made to produce reliable and valid measures of exergaming participation[28] in order to properly monitor the prevalence of participation in exergaming. Evidence on motivation, preferences, intentions and sustainability is critical to informing the design and implementation of exergaming interventions[28,62] with the potential to improve levels of PA that can be sustained. It has been argued that exergaming research and its potential is underexploited. In order to achieve exergaming's most beneficial effects, exergames must be tailored to the target population and measurement tools are needed to understand the target variables.[57] More information is needed for customization of games and interventions including adaptivity, specificity and individuality in a more systematic fashion in terms of which characteristics of exergamers and exergames promote health behaviours. There is a need to investigate behaviour change in terms of PA, how we can help youth become more active and whether this can be accomplished through exergaming. By using gamified augmented reality (exergaming), we may be able to help youth attain recommended PA levels and promote sustainable healthy behaviour while enhancing enjoyment of PA.

1.4 The Present Research

1.4.1 General objective, focal research question/problem, rationale and research gaps

There have been numerous calls for studies that identify factors that motivate youth and young adults (defined herein as those aged up to 30 years old) to participate in PA and to sustain PA in the long-term.[66,126] The evidence pertaining to exergaming to date, collected primarily in controlled laboratory settings, suggests that exergaming may help youth sustain PA.[28-31,67,83] However, a major gap in this literature relates to investigations conducted in population-based samples in order to: (i) assess whether exergaming is sustainable in real-life settings; (ii) describe the characteristics of youth more likely to sustain exergaming, and (iii) determine whether

motivation, intentions or preferences are important in exergaming.[28-31,67,83] This dissertation will increase understanding of the contribution of exergaming to PA and, guided by the SDT, increase understanding of the role of motivation in exergaming behaviour.

The questions that drive the three studies described in this dissertation are: What is the contribution of exergaming behaviour to PA? How can we better understand the role of motivation in PA and exergaming? Is exergaming sustainable in real-life settings in youth? In the affirmative, what are the characteristics of young exergamers who sustain exergaming behaviour over time? And finally, what are the motivations, circumstances and intentions that are important in exergaming behaviour?

1.4.2 Specific objectives

(i) To identify gaps in the exergaming literature that guide research and practice

(ii) To identify factors (including level of motivation for PA) associated with sustained exergaming

(iii) To describe the psychometric properties of a newly developed Reasons To EXergame scale (RTEX) which evaluates motivation to exergame, and whether and how the RTEX relates to exergaming behaviour

CHAPTER 2

STUDY 1

EXERGAMING IN YOUTH: A NARRATIVE OVERVIEW

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ABSTRACT

Objectives. Because of the rapid evolution in exergame technology and gaming content, the literature on the health benefits of exergaming needs ongoing review. Updated syntheses incorporating quality assessments of included articles can provide evidence for research and practice. The objective of the study was to summarize evidence from systematic reviews and meta-analyses on the associations between exergaming and: 1) PA, sedentary behaviour or EE; and 2) body composition, BMI or weight outcomes among persons under age 30 years; and to summarize recommendations in the articles retained. **Methods.** The Elton B. Stephens Co. (EBSCO) database for reviews was searched from January 1995 to December 2016. Data were extracted from articles that met the inclusion criteria by two independent reviewers, quality scores were attributed to each article, and a narrative synthesis was undertaken. Recommendations for future research, intervention development and game design were also extracted. **Results.** Twenty-five reviews, each of which incorporated between 5 and 100 articles. Sixteen assessed the evidence on the association between exergaming and PA, EE and/or sedentary behaviour and nine examined the association with body composition or weight. There was substantial heterogeneity across reviews in objectives, definitions and methods. A positive relationship between exergaming and EE is well-documented but whether exergaming increases PA or changes body composition is not established. There is, however, evidence that exergaming is a healthier alternative to sedentary behaviour, improves cognitive function, is an interesting and enjoyable pastime for youth and shows promise as a PA option that adds variety and alternative forms of PA in health and diet interventions. **Conclusions:** Exergaming is likely more health-promoting than traditional videogames because of higher EE and possibly improved physical fitness, body composition and cognitive health. However, more research and longitudinal studies are needed to assess whether exergaming reduces sedentary time and has health benefits. We recommend that exergaming interventions be designed using behaviour change theories and that future reviews use standard review criteria and include a section on research recommendations. Exergaming is likely more health-promoting than traditional videogames because of higher EE and possibly improved physical fitness, body composition and cognitive health. However, more research and longitudinal studies are needed to assess whether exergaming reduces sedentary time and has health benefits.

2.1 INTRODUCTION

Physical inactivity is the fourth leading risk factor for mortality among adults globally after high blood pressure, cigarette smoking and high blood glucose.[127] Yet few youth meet recommended PA levels (about 40% of Canadian children and youth aged 5 to 17 years meet the recommended targets for PA in 2016-17).[6, 128-130] The benefits of PA among youth include healthy growth of the musculoskeletal and cardiorespiratory systems, maintenance of energy balance and normal weight, a lower risk of hypertension and high blood cholesterol, and better sleep.[131] Mental health benefits include higher cognitive function, mental well-being, improved self-esteem, body image and competence and the opportunity for social interaction, achievement and recognition; youth who do not meet current PA guidelines are more likely to report psychological and emotional problems.[132-141] Lack of PA is a cause of recent increases in childhood obesity and of the increased insulin resistance, disturbed lipid profiles and elevated BP in children that underpin the increasing prevalence of type 2 diabetes in youth.[142-145] Because PA levels established in youth track into adulthood,[4] there is an urgent need for population-based interventions that help youth establish physically active lifestyles early in life.

A newcomer to the line-up of PA alternatives is exergaming (i.e., active videogame-playing), an innovative contemporary option[146,147] with potential to increase PA and decrease sedentary behaviour. Exergaming offers an accessible, relatively low-cost PA alternative that is especially attractive to youth and young adults in our increasingly technophilic society.[148] In addition, exergaming allows children and youth to engage in PA independently, without the need for adult supervision. In 2010, nearly 40% of U.S. students in grades 9-12 exergamed at least one day per week,[149] 25% of Canadian youth ages 15 to 18 years reported exergaming in the past week[148] and up to 20% of young Canadian adults exergamed 1-3 times a month or more.[150] Underscoring its popularity, 83% of U.S. youth ages 8-18 years have a traditional videogame console at home, 56% own two or more consoles,[33] and many report playing traditional videogames for an hour or more daily.[33] Many of these traditional videogame consoles have add-on exergaming equipment, and exergaming consoles can be bought separately. In 2009, U.S. retail sales of videogames totalled more than $19.5 billion.[151] Common exergames include interactive aerobic fitness games, dance simulation games, interactive cycling games, isometric resistance games and sports simulation games.[31] Exergaming consoles including Microsoft's Kinect XBOX 360, Nintendo's Wii & Wii U and PlayStation Move, use input devices such as

accelerometers and gyroscopes, vision-based devices, ergometers (i.e., exercise equipment), pressure and touch sensors (i.e., pads and mats) and special purpose devices to detect and process the player's motions as well as interact with the player.[31] Mobile exergaming or Augmented Reality game using a cell phone or tablet with an app is also popular.[152] With mobile or Augmented Reality exergaming such as Pokémon Go[21], the real world becomes the 'game map' or playground, and players obtain health benefits through movement,[152] although its safety and sustainability have been questioned.[153] The recently released Nintendo Switch allows users to exergame outdoors, and to travel with their exergame consoles.

Because of its widespread popularity,[36] there is increasing interest among researchers in understanding the health benefits and/or harmful effects of exergaming.[83,153,161] It is hypothesized that exergaming increases EE through PA, and decreases sedentary behaviour (e.g.,[74,154]). The effects of exergaming on body composition, body weight (e.g.,[155]) and health (e.g.,[156]) have been investigated in both experimental and observational research. With the number of studies on exergaming increasing rapidly, reviews summarizing the evidence on exergaming outcomes have begun to emerge. A review of reviews is a well-established method to synthesize knowledge[157,158] and an impactful way of highlighting the main messages from previous research to inform interventions, end users (such as clinicians) and future research.[159] Position statements on exergaming as an option to increase PA[160] and decrease obesity,[161] as well as responses to these position statements[162] have also been published. However, reviews of the effects of exergaming on a comprehensive range of health outcomes in youth have not yet been published. Kari et al. (2014)[30] published a review of six reviews that focused on PA and fitness only[30] and concluded that exergaming may improve these PA and physical fitness (e.g. EE).[30] Parisod et al. (2014)[163] published a review of reviews that focused on youth under age 18 and digital health (including exergames) and concluded that higher quality reviews indicated positive results of exergaming on PA indicators, and that sedentary games had the potential to teach youth about their health (ex. about asthma and diabetes). Our objective in this current review of reviews published up to December 2017, was to synthesize the results from systematic reviews and meta-analyses on the association between exergaming and sedentary behaviour or EE, body composition or weight and health (physical, mental and cognitive) in youth. In addition, we summarized recommendations that emerged from the reviews retained on future research, exergaming intervention development and game design.

2.2 METHODS

We conducted a narrative overview to summarize the results of reviews that met our inclusion criteria.[159] According to Petticrew and Roberts,[164] there are three stages in a narrative synthesis: (i) the studies retained are organized into discrete logical categories that relate to the research question (in this case, health-related outcomes); (ii) a within-study analysis is conducted which summarizes the description, findings and study quality. The data are usually presented in a table's format; and (iii) a cross-study synthesis is conducted which provides a global summary of the research while accounting for variability across studies.

2.2.1 Selection of Reviews

We searched the Elton B. Stephens Co. (EBSCO) database (which incorporates the following databases: Communication & Mass Media Complete, Computers & Applied Sciences Complete, MEDLINE, Psychology and Behavioural Sciences Collection, PsycINFO, SocINDEX, SPORTDiscus, and education Source) from January 1995 to January 2017 using search terms including exergaming/gam*, exergaming, reviews, review, and review literature. We also performed a manual search on Google Scholar. Reviews retained for data abstraction were identified independently in three steps by two authors (EO, HD). In Step 1, titles were reviewed. In Step 2, abstracts of the reviews retained after Step 1 were reviewed. In Step 3, the full texts of the reviews remaining after Step 2 were screened. At each step, reviews clearly not eligible based on pre-determined inclusion and exclusion criteria were rejected. Any discrepancies between reviewers at each step were discussed and resolved. Inclusion criteria were that the review: (i) was systematic or a meta-analysis of observational and/or experimental studies; (ii) synthesized articles on the relationship between exergaming and any of PA, sedentary behaviour, EE, body composition, body weight or a combination of these outcomes; and (iii) included articles in which participants were age 0-30 years (several reviews including participants >31 years were retained if the results for younger participants were reported). Reviews were excluded if they: (i) did not focus exclusively on exergames, (ii) did not report the method used to select articles, (iii) investigated only persons age >31 years or results for persons ≤30 years could not be extracted; (iv) were conducted in the context of rehabilitation (e.g., balance rehabilitation); or (v) assessed exergaming in a school setting as one component of a multicomponent intervention.

2.2.2 Quality rating

EO and HD independently assessed the quality of each review retained according to a scoring system that incorporated elements from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), A Measurement Tool to Assess Systematic Reviews (AMSTAR) and Critical Appraisal Skills Programme (CASP) criteria).[165-167] Each review was scored according to the 16 criteria listed in Table 1 (0=not attained, 1=somewhat attained, 2=fully or almost fully attained), for a total score ranging from 0 to 32.

Table 1. Score for Each Review Criterion for Each Review*

	Article reference																								
Section/topic	168	169	170	171	172	173	174	145	175	31	62	176	25	26	177	29	178	119	179	180	181	182	183	184	185
TITLE -- Identifies report as systematic review or meta-analysis																									
Title	0	2	2	2	0	2	0	0	2	1	2	0	2	0	2	2	2	2	2	2	0	2	2	2	0
ABSTRACT - Provides structured summary (background; objectives; data sources; study eligibility criteria, participants, interventions; study appraisal and synthesis methods; results; limitations; conclusions, implications and registration number).																									
Structured summary	2	2	0	2	1	2	2	1	2	2	2	1	2	2	2	2	2	2	1	2	1	2	2	1	1
METHODS Eligibility criteria - Includes list of studies included and excluded Information sources - Describes information sources (databases with dates of coverage, contact with authors to identify additional studies) in the search and date last searched. Search - Was a comprehensive literature search performed? At least two electronic sources should be searched. Study selection - States process to select studies (screening, eligibility, included in systematic review, and included in meta-analysis). Duplicates - Was there duplicate study selection and data extraction? There should be at least two independent data extractors and a consensus procedure for disagreements should be in place.																									
Eligibility criteria	1	2	1	2	1	1	1	1	2	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	1
Information sources	2	2	2	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0
Search	2	2	2	0	2	2	2	0	1	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0
Study selection	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	0
Duplicates	1	2	2	2	0	2	0	0	1	0	2	2	2	2	0	2	2	2	2	0	0	2	2	2	0
RESULTS Study selection - provides number of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow chart Study characteristics - presents characteristics for which data were extracted (study size, follow-up period) and provides citations. Results of individual studies - For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot																									
Study selection	2	2	2	2	1	2	1	1	2	2	1	2	2	2	2	2	2	2	2	2	0	2	2	1	0
Study characteristics	2	2	2	2	1	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	1	2	2	2	0
Results of each study	2	2	2	2	2	1	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
DISCUSSION Summary of evidence - summarizes findings including strength of evidence for each outcome; considers relevance to key groups (healthcare providers, users, policy makers) Limitations - discusses limitations at study and outcome level (risk of bias), and at review-level (incomplete retrieval of articles, reporting bias) Conclusion - provides general interpretation of results in the context of other evidence and implications for future research. Quality assessed - Quality of included studies assessed, documented (using standardized approach)																									
Summary of evidence	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	1
Limitations	2	2	2	2	1	2	1	1	2	2	2	0	1	2	0	2	2	0	2	2	0	2	2	0	1
Conclusion	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	1	2	2	2
Quality assessed	0	1	1	2	0	2	0	0	2	0	0	0	0	0	2	0	2	2	0	2	0	2	2	2	0
Funding - Describes sources of funding and other support (supply of data); role of funders Conflict - Were conflicts of interest included? Potential sources of support should be acknowledged in both the systematic review and the included studies.																									
Funding	0	2	2	0	0	2	0	0	0	2	2	2	0	2	0	2	2	2	0	2	0	2	2	2	0
Conflict	2	2	2	2	0	2	0	0	0	2	2	0	1	2	2	0	2	2	0	0	2	1	2	2	0
TOTAL	26	31	26	24	19	25	21	20	30	22	24	23	22	23	23	29	31	27	25	29	16	28	30	27	8
*0 = no; 1 = somewhat; 2 = yes																									

2.2.3 Data extraction

Data were extracted independently from each review retained by EO and HD using standardized data extraction forms. Extracted data included: demographic subgroup(s) targeted in the review, time frame of search, number of papers included, data sources, type of review, whether the review assessed the quality of the studies included, the primary outcome, other outcomes, the

main findings, and whether any theories or guiding frameworks were mentioned. When more than one outcome of interest was reported in a single review, only the primary results (defined as the results presented either in the results section or the abstract) were extracted. Other outcomes are reported as additional information in Tables 2 and 3.

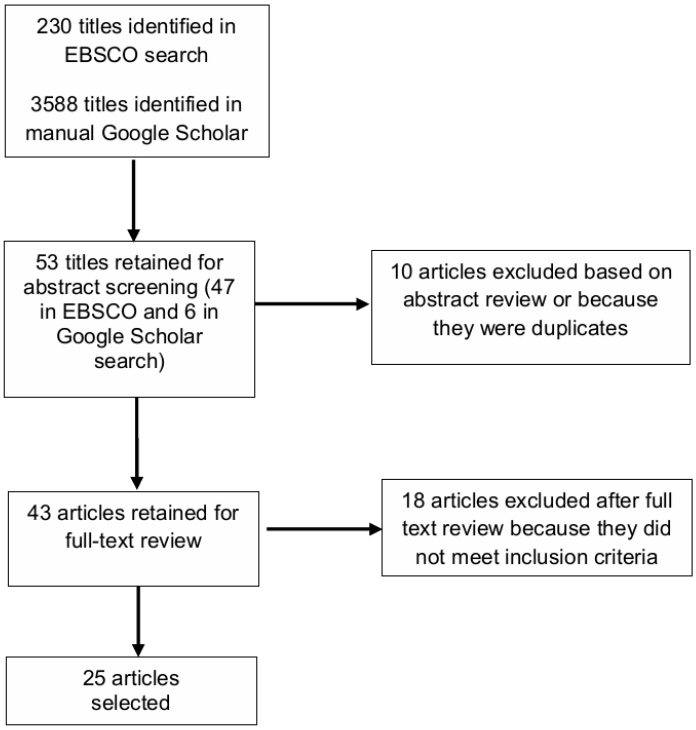
Recommendations pertaining to game design, intervention development or future research were extracted from the discussion and recommendation sections of each review (Table 4). The frequency with which a specific recommendation was mentioned across reviews was recorded. Reviewers were not blinded to the names of the author or the titles when extracting data.

2.3 RESULTS

2.3.1 Overview of reviews retained

Twenty-five reviews were retained for data extraction (Figure 1), each of which incorporated between 5 and 100 articles that spanned 1985 to 2017. Appendix E describes the reviews retained at the title, abstract and full article review stages, as well as reasons for exclusion. Reviews retained were published in 2009 (n=1), 2010 (n=2), 2011 (n=4), 2012 (n=1), 2013 (n=5), 2014 (n=6), 2015 (n=4), or 2016 (n=2). All reviews were published in English except,[176] which was published in French. Most studies were conducted in North America, the U.K, Asia or Australia. PubMed was the source of most reviews retained (n=22). Twelve reviews were systematic; three were meta-analyses, and one reported both a systematic review and a meta-analysis. Nine reviews did not report the specific type of review (i.e., "literature review"; "overview of available literature on exergaming and EE"; "survey of the literature"). The meta-analyses reported effect sizes (Hedge's g) with outcomes including EE, VO_2 max, heart rate, metabolic equivalents and change in body composition. Because of wide heterogeneity across studies, the meta-analyses included fewer individual articles than the systematic reviews. Twelve of the 25 reviews assessed the quality of the studies retained and most reported generally low quality due primarily to short follow-up periods and absence of a control group. Only five reviews discussed whether the studies included used a conceptual framework, theoretical model or theory to guide the research.

Figure 1 - Description of Stages of Article Selection and Retention



2.3.2 Exergaming and PA, EE and Sedentary Behaviour

Sixteen reviews covering 496 articles (with 50% appearing in more than one review), examined the association between exergaming and PA, EE and/or sedentary behaviour (Table 2). Reviews that included laboratory experiments examining the acute effects of exergaming on EE (e.g.[31,169,176]) concluded that most exergamers had higher EE over a resting state when exergaming with increased heart rate, VO_2 max, and EE. For example, Pasco et al. (2011)[176] found that compared to resting state, exergaming increased EE by 222% (range: 100-400%) and heart rate by 64% (range: 26-98%) on average. Type of exergame (e.g., Wii sports, Dance Dance Revolution) was important. Most games elicited light-to-moderate PA but dance and boxing exergames elicited higher EE. Overall, lower and full body movement exergames produced higher EE, heart rate and VO2 compared to games that involved the upper body only.

Table 2. Data extracted from reviews on the association between exergaming and physical activity (n=16)

Ref.	Age/group	Search time frame	No. papers	Data sources	Type of review	Study quality assessed	Outcome(s)		Main findings for youth	Theory invoked
							Primary	Other		
Campos & del Castillo, 2016[25]	Children, adolescent, adults, older adults	Jan to Jul 2015, articles spanned Jan 2010 to Jul 2015	100	Cochrane Central Database, ERIC, Google Scholar, ISI Web of Knowledge, MEDLINE/PubMed, Scopus, SPORT Discus. Grey literature also included.	Systematic	No	PA *Only PA is described in findings*	Intellectual skills, knowledge, motor skills, physical properties, motor skills, disease and injury awareness, prevention and management, fitness	Exergaming increases capacity in PA and education 87 studies reported improvement in fitness, 39 supported that exergaming improves physical properties, 29 showed no significant results Exergaming reduced the risk of obesity, hypertension, congestive heart failure, atherosclerosis and cardiovascular disease	PA interventions designed and measured using behavioral theories are more likely to be successful than traditional exercise modalities.
Pasco et al., 2011[176] Article in French	Youth (up to age 34 years).	Up to Sept 2010	26 total (17 (EE) 9 (PA))	Web of Science, PubMed, EBSCO Host (Academic Search Premier; Eric; PsycInfo; PsycArticles; Science Reference Center; SportDis	Systematic	No	EE, HR, PA	Cognitive and psychosocial variables, behavioural outcomes	Exergames increase EE and HR compared to sedentary videogaming. Evidence is mixed on whether exergames engage children in activity levels consistent with public health recommendations for PA and improving	No

				cus; Teacher Reference Center; E-Journals; CINAHL with Full Text; CINAHL Plus with Full Text					cardiorespiratory fitness More investigation needed to confirm the benefits of exergames to promote PA. Compared to rest, EE increased by 222% on average and HR by 64% on average Games requiring lower body movement only result in higher HR and EE than games that require only upper body movement. PA is more intense in games that require only lower body movement and games that require both upper and lower body movement than games just involving the upper body. Exergaming related to a moderate increase in PA at home and a slight decrease in sedentary activity.	
Tabak et al., 2015.[26]	All ages	Searched between Jan 2004 and Jun 2014. Manual search until Jul 2014	11	PubMed, Web of Science, Association for Computing Machinery Digital Library, manual search of relevant journals, reference lists of included studies	Systematic	No (but evaluated technology using Staged Approach to Evaluation of Telemedicine of DeChant)	PA in daily life and where the game has specific goals, rules, and feedback (step count, time for exercising)	Game elements, feedback mechanism	Clinical effectiveness and added value of gaming in changing daily PA not established. Additional efficacy trials needed to establish impact of mobile exergaming applications on daily PA. 2 RCTs showed no effects on activity behaviour. More efficacy trials needed to establish impact of mobile exergaming on daily PA.	Discussed if mobile app was designed using theory (n=4). Mentioned: Goal Setting Theory; Social Comparison, Ecological model of health behaviour change for PA, Cognitive Dissonance Theory; Behavioral model of Fogg, Goal Setting Theory and Self-determination theory
Liang et al., 2014[169]	Youth (≤18 years)	Jan 2000 to Aug 2013	54 (32 studies examin	n ISI Web of	Systematic	Yes - only interventi	Effect of exergaming on 1.		Exergaming led to light-to-moderate intensity PA in	5 studies used behavior

			ed outcome 1; 22 studies examined outcome 2)	Knowledge, Medline, SCOPUS, SPORTDiscus, and Ovid databases (AMED, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, Cochrane Central Register of Controlled Trials, Embase, Ovid MEDLINE). Reviews were searched for useful references.		on studies with PA comparison groups or across time were assessed	EE or PA levels 2. habitual PA or change in PA		studies of immediate PA outcomes. In the home setting, exergaming did not increase children's PA. Moderate evidence that structured exergaming improves PA. Inconclusive evidence of the effect of exergaming on PA in multiple settings Exergaming elicits light-moderate PA intensity. Inconsistent findings on EE obtained when samples were divided by BMI. 8/15 intervention studies found positive effects of exergaming on PA outcomes, cognitive and psychosocial variables, behavioural outcomes and physical fitness. Exergaming had larger effects on cognitive and psychosocial outcomes than behavioural outcomes. No effect of exergaming on PA in the home setting. Moderate evidence that structured exergaming promotes PA.	theory in exergaming intervention
Sween et al., 2014 [31]	All ages (5 studies >18 years old)	Articles published between 2002 and 2012	27	PubMed, reference list of selected reviews	Overview of literature on exergaming and EE	No	Effect of exergaming on EE	PA intensity	Exergaming and EE strongly correlated. Most exergaming achieved moderate PA levels. Increased duration of exergaming may help attain ACSM guidelines for health and fitness. Dance simulation games demonstrated the highest increases in EE. EE levels may depend on perception and exergaming experience. EE up to 300% above resting levels.	No

Peng et al., 2011[62]	All ages: adults (n=6) and children	Jan 1995 to Oct 2010	18; n=354	Communication and Mass Media Cochrane Library, Medline, PsychInfo, PubMed, SPORTDiscus, Web of Science. Ref lists in 16 included articles, Social Science Citation Index, relevant literature review papers, email request of data from authors of 9 studies.	Meta-analysis (random effects model; Q and I^2 statistics examined heterogeneity; Hedge's g for effect size)	No	HR, EE, VO2. Q and I 2 statistics for effect size	Moderators examined: exergame type (upper, lower, whole body movement), age (6-17 years; ≥18 years), weight (normal vs. overweight or obese)	Exergaming increased HR, VO2 and EE compared to at rest. Effect size for exergaming on HR, VO2 and EE across exposures were similar in exergaming and traditional PA. Exergame type did not moderate HR Player age was a significant moderator for the effects of exergaming VO_2. Lower and whole-body movements produced more EE than upper body systems. Weight status did moderate HR, EE, VO_2.	No
Biddiss et al., 2010[29]	Children and youth ≤ 21 years	Jan 1, 1998, to Jan 1, 2010	18	ISI Web of Knowledge, PubMed, Scholars Portal	Systematic	Yes, the RCTs (using the PEDro (Physiotherapy Evidence Database) evaluation scale.	EE during exergaming vs. during sedentary or passive videogame activities. Measuring % increase in HR and EE, and child-specific METS of task.	Activity patterns: PA promotion in the home (daily use, efficacy for change), physiologic measures, enthusiasm, enjoyment, interest, physiological risks and benefits, enjoyment, motivation	Exergaming increased EE to light or moderate activity levels. Child-specific METS of exergame ranged from 2.0[13] - 5.0[36] (mean (SD) = 3.3 (1)) (n=17). % increase in EE during exergaming from resting values was 222% (SD=100%, range=26-98%) (n=21). % increase in HR from resting values was 64% (SD=20, range=26-98%) (n=17). % increases in HR and EE were variable. EE was significantly lower for games that required upper body movements than those that engaged the lower body as well.	No
Peng et al., 2013[178]	Adults (n=18) and children	search time frame - Jan 1995 to Oct 2010, and	13 interventions and 28	Cochrane Library, PsychInfo, PubMed, SPORTD	Systematic	Yes, for intervention studies (Norman	Laboratory studies: PA intensity	Sex differences, exergaming enjoyment	All laboratory studies showed that exergaming produces light-to-moderate intensity PA. 3 intervention	No

		Oct 2010 and Mar 2011 (2 waves). The 41 studies were published between 2002 and 2011	laboratory studies	iscus, Web of Science		et al., 2007)	Intervention studies: increase in PA		studies supported that exergaming increases PA or exercise attendance. Exergaming equivalent to light-to-moderate PA. 9/9 intervention studies among youth demonstrated that exergame use declined if self-directed Findings in youth and adults: exergames preferred over traditional exercises. 18/28 laboratory studies reported sex differences 3/13 intervention studies found exergame group increased amount of PA or exercise (These findings may include 2 reviews restricted to seniors)	
Barnett et al., 2011[180]	Youth (≤18 years)	Start of database to Mar 2009	9 articles examined EE during videogame play, 4 examined exergaming (13 total)	PubMed, ScorpusScopus, SPORTDiscus, Ovid MEDLINE, PsycInfo, and EMBASE. Search of ref list, all authors and citations of all full text articles.	Systematic and meta-analysis	Yes	EE, exergaming maintenance, PA intensity during exergaming (mean MET values from resting EE)	Maintained exergaming, type of game, sex, age	Meta-analytic estimate of minimum METs was 3.1 (95% CI:2.6, 3.6), and the estimate of maximum possible METs was 3.2 (95% CI: 2.7, 3.7). No games elicited an average EE above 6 METs. Most studies reported exergame use declined over time. The only group that increased in play across time were those exposed to a multiplayer condition (not statistically significant). Exergaming can generate EE in youth to attain PA guidelines. Few studies assessed exergaming sustainability, which appears to diminish after a short period of time in most players	No
Carmo & Palmeira, 2013[175]	Youth ≤18; only RCTs and experimental studies	1 Jan 2008 and 11 Jun 2012	10 (8 RCTs and 2 experimental	PubMed, relevant references from included articles	Systematic	Yes	PA	Measures of body composition, environment, waist	Some evidence that exergaming promotes light to moderate PA. GameBike increased aerobic fitness and	No

			studies)					circumferen ce, motivation, sedentary screen time, continuous participatio n in exergaming	reduced body fat and total cholesterol in overweight and obese children. 2 RCTs reported no difference in PA in intervention vs. control groups. 1 two-arm parallel trial showed that exergaming had a small positive effect on BMI and body composition in overweight children. 1 RCT concluded that exergaming had a positive effect on body composition in overweight or obese children. EE is lower for exergames compared to traditional versions of the same games	
Foley & Maddiso n, 2010[174]	Youth ≤18	Studies published after 2000-Dec 2008	19	Medline, PubMed, Embase, PsycInfo, Cinahl, Cochrane RCT Register, screening ref lists of eligible articles.	Not reported	No	EE, PA	CVD fitness or body compositio n, HR, oxygen consumptio n	Compared to traditional videogames, exergaming elicited greater EE similar in intensity to mild to moderate intensity PA. Intervention studies indicate that exergaming may increase free-living PA and improve body composition Arcade-style active games elicit EE elevated above rest. Games requiring whole-body movement resulted in highest EE (4.8-5.0 METS) with upper-body dominant games resulting in light intensity movement (2.3-2.9 METS). 5 studies found a trend for greater HR, oxygen consumption or EE in boys playing active games compared to girls, although few statistically significant differences existed. Exergaming elicits greater EE compared to rest and traditional nonactive videogames, as well as other common	No

									sedentary behaviour activities (TV).	
Guy et al., 2011[179]	0-18 years	Dec 2012, articles span 1998 to 2011	34	EMBASE, and PubMed, references from a literature review	Systematic	No	PA during exergaming	nutritional outcomes	PA during exergaming contributes to daily recommendations of PA. Some benefit of gaming (increased PA, nutritional knowledge) suggesting that videogames might combat childhood obesity	No
Best, 2013[185]	Youth	Not reported	Not reported	Not reported	Not reported	No	Physical health (PA, physiological response, enjoyment, motivation, increase PA over time, improve physical health) and cognitive functioning Connection between physical health and cognitive functioning	N/A	Unclear whether exergaming can improve physical health. Exergaming may enhance executive functioning in youth and youth with ASD. Exergaming increases EE beyond sedentary gaming but does not achieve moderate to vigorous intensity PA. No evidence in RCTs that exergames increase daily engagement in moderate to vigorous intensity PA. Unclear whether exergaming promotes PA in youth.	No
Altamimi et al., 2012[172]	0–18 years	N/A	71 articles (41 articles, 24 conference papers, 5 books, 1 website)	ACM Digital library, IEEE Explore, Science Direct, some journal databases Includes grey literature.	Survey of literature	No	HR, EE,	Child health and development; physiological effects, fitness, psychologic and behavioural outcomes	. Exergames increase PA in children Exergaming influences EE and HR. Exergaming results in higher EE compared to SB The new generation of videogames which require physical interaction, provides opportunity for children to play. Exergaming motivates people to exercise and encourages adherence to exercise	No
Gao et al., 2015[183]	0–18 years	1985-2015	35	Academic Search	Meta-analysis	Yes	EE, HR, VO2 max,	Body composition, CVD	Compared to SB, exergaming had	Some outcomes included

				Complete; ERIC; Medline; PubMed; PsycINFO; SportDiscus; Scopus and EBSCO			MET, PA, perceived exertion	fitness); psychological outcomes (self-efficacy; enjoyment, liking, attitudes, intention, situational interest, intrinsic motivation towards exergaming)	large effect on health. Comparison of exergaming to lab-based exercises showed that effect sizes for physiological outcomes were marginal Comparison between exergaming and field-based PA had null to moderate effect sizes. Exergaming may yield health benefits in youth equivalent to lab-based exercise or field-based PA. Exergaming may be a good alternative to SB and an addition to traditional PA and sports in youth. Effect size of EE favored exergaming over SB (Hedge's g = 2.74). Exergaming demonstrated large effect size margins compared to SB for all PA outcomes. Compared to lab-based exercises, HR favored exergaming (Hedge's g = 1.55); all other variables were similar across groups. Compared to field-based PA, cardiovascular fitness demonstrated moderate effect sizes for exergaming while other outcomes had small effect sizes. Exergaming produced effects on moderate to vigorous intensity PA equivalent to field-based PA. Exergames requiring whole or lower body movement had effects on outcomes like field-based PA. Different types of exergames had marginal to small effects on the outcomes compared to field-based PA.	variables from theories

LeBlanc et al., 2013[173]	0 to –17.99 years	No limits on dates, no search period discussed	51	MEDLINE, EMBASE, psycINFO, SPORTDiscus, and Cochrane Central Database. References extracted from OVID, EBSCO, Cochrane	Systematic	Yes, used grade framework	Habitual PA, acute EE (VO_2) EE	Adherence and appeal, opportunity cost, adiposity, cardio metabolic health, energy intake, adaptation learning and rehabilitation, and videogame evolution/ Adherence, appeal, opportunity cost, adiposity, cardiometabolic health, energy intake	Compared to SB, exergaming increases light to moderate PA. Exergaming is associated with acute increases in EE; effects on habitual PA are not clear. Exergaming shows promise when used for learning and rehabilitation in special populations. Evidence related to other indicators was limited and inconclusive. Unable to elicit PA high enough to meet PA guidelines Exergaming is appealing but no evidence for sustainability Inconclusive evidence on effect of exergaming on energy intake, cardiometabolic health indicators, opportunity cost.	No

SB: Sedentary behaviour; PA: Physical activity; EE: Energy expenditure; HR: Heart rate; RPE: rate of perceived exertion; BMI: Body Mass Index; SES: Socioeconomic status

Differences by age were reported in reviews that examined a range of ages. Specifically, youth had higher EE than young adults when playing similar games. Potential moderators of the association between exergaming and PA or EE included weight status - overweight and obese individuals reported more enjoyment and higher EE than normal weight individuals. Persons with more exergaming experience reported increased enjoyment, played longer and had higher EE. In contrast to laboratory studies, research conducted in real-life environments (i.e., at-home interventions) generally concluded that EE in the home environment was not well-measured, and that virtual sports simulation games cannot replace traditional games in terms of EE.[169,176,184] It was unclear whether exergaming increases general levels of PA.[169,176,184]

Although numerous authors strongly advocated that exergaming should replace non-active screen-time, no reviews focused specifically on the association between sedentary behaviour and exergaming with the exception of,[176] which reported that exergaming related to a moderate increase in PA at home and a slight decrease in sedentary activity (Table 2).

Because many studies were laboratory-based and/or cross-sectional, there was no clear evidence that exergaming increased PA over time. Most experimental studies discussed in the reviews reported little or no change in total PA and the evidence from observational studies was generally unclear. Four meta-analyses that addressed these outcomes[62,170,171,183] reported that effect sizes for playing exergames on heart rate,VO2 max, and EE were similar to those for traditional PA,[62,170,171,180,183] and that type of game and player influenced the effect size. Multi-player modes, playing with others and competition seemed to encourage adherence and sustainability, which increased PA.[27] In longitudinal studies, exergaming decreased over time and compliance with the interventions was higher in studies of shorter duration.[83,184] Interventions tested were generally less than 28 weeks. The reviews generally recommended longer, higher quality studies with larger sample sizes, and that long-term exergaming in the home environment should be investigated (Table 4).

2.3.3 Exergaming and body composition or weight

In nine reviews covering 112 articles (with 33% appearing in more than one review), the evidence on whether exergaming is associated with changes in body composition or weight was mixed. Several reviews (e.g.[177,179]) suggested that video- and exergames improve PA, nutritional knowledge, body composition and weight. For example, one review[27] reported that body composition changed significantly, but only in African-American youth. However, other reviews did not support exergaming as a method to change body composition. Zeng and Gao[168] reported that four RCTs suggested that exergaming had a positive effect on BMI, body composition or body fat, but exergaming did not influence adiposity in three other RCTs. In addition, Gao and Chen[184] found that 4 of 18 studies found no significant differences across groups in PA, BMI or weight loss. One review[119] found that only four (of 14) studies reported differences in obesity outcomes among overweight or obese children; one found a significant reduction in the first half of the intervention, and another among girls only. Van't Riet et al. (2014)[171] reported a small, nonsignificant, positive composite-effect size of exergaming on children and adolescents' BMI : Hedges g=0.20 (95% CI: -0.08, 0.48). Finally, one review reported a study with a small effect of a 24-month trial at 6 months. However the effect was no longer apparent at the end of the intervention.[170] The reviews generally recommended that, to improve body composition,

exergaming should be incorporated into a multicomponent intervention. Further, exergaming appeared to be an activity enjoyed by participants (Table 3).

Table 3. Data extracted from reviews on the association between exergaming and body composition/weight (n=9)

Ref.	Age/group	Search time frame	No. papers	Data sources	Type of review	Study quality assessed	Primary outcome	Other outcomes	Main findings for youth	Theory invoked
Chen & Wilkosz, 2014[177].	12–18 years	Jan 1990-Jan 2014	14 RCTs and pre-post studies	CINAH. Embase, PubMed, PsycInfo, Cochrane Library, refs. of included articles were hand-searched	Systematic	Yes - Cochrane Effective Practice and Organization of Care Review Group and recent systematic reviews	BMI, body fat	PA, diet, psychosocial function (depression, self-esteem, efficacy, Behaviour Assessment Scale)	All effective interventions incorporated dietary and PA strategies. Both exergaming and Internet interventions including diet and physical components have the potential to decrease obesity in adolescence, especially Internet-based interventions. Significant decrease in BMI or % body fat after exergaming or internet-based intervention. Short- and long-term (9 months post intervention) effects were observed. Internet and exergaming interventions improved PA, dietary and psychosocial outcomes. Intervention intensity (weekly exergaming/PA sessions) has the potential to decrease obesity. Unclear if internet or exergaming is more effective.	No
Zeng & Gao, 2016[168]	8-19 years, Obese/overweight individuals	Jan 2010 and May 2016	12 (Interventions only with obese individuals)	Academic Search Complete, Communication and Mass Media Complete, ERIC, PsycINFO, SportDiscus, and Medline.	Systematic	No	BMI, % fat, change in skinfold thickness, waist circumference, waist-to-hip ratio, bioimpedance, body composition,	Changes in self-efficacy, HR, maximum volume of Oxygen, skill-related fitness, EE, HR, MET, blood pressure, cholesterol, triglycerides, glucose, insulin	Exergaming may elicit health benefits in overweight or obese people. Evidence that exergaming influences adiposity is inconclusive: 4 RCTs indicate that exergaming had a positive effect on BMI, body composition or body fat. 3 RCTs reported that exergaming did not influence adiposity. 3 of 4 RCTs reported that exergaming had no effect on physiological outcomes. 1 RCT reported that absolute EE was higher in obese children, but maximal HR was lower than in lean participants. Exergaming shows promise in motivating and	No

									engaging youths in PA.	
Bochner et al., 2015[170]	<19 years	Up until May 30, 2013	7	PubMed, Embase, Web of Science, Cochrane Library, and PsycINFO	Meta-analysis of RCTs trials	No-studies assessed for bias by extraction of key quality measures from the Cochrane Handbook	Standardized mean difference of weight change (kg) between intervention and control groups at week 10-12	No	No difference in pre-post intervention weight change between exergame and control group which continued daily routine). a well-powered study with a 24-month follow-up period, reported a small effect of a 6-month exergaming intervention on body composition in overweight/obese children age 10-14.	No
Gao & Chen, 2014[184]	≤18 years	Articles published from 1985 to 2013	34	Academic Search Complete, ERIC, Medline, PubMed, PsycINFO, SportDiscus. Bibliographies of published reviews were cross-checked with results from search engines.	Systematic	Yes	PA and obesity-related outcomes (weight loss, body com-position, waist circumference,)	Psychosocial outcomes (intrinsic motivation, enjoyment, liking, situational interest, self-efficacy, self-worth, attitudes, intention, social support, outcome expectancy and social cognitive factors), EE, HR, Vo2, METs, PA level, rate of perceived exertion, cardiovascular fitness	Effects of field-based exergames on children's habitual PA, weight loss and body composition are unclear due to methodological concerns. Exergaming appeals to children, but strategies are needed to sustain their interest. 2/18 RCT and control trials indicate that exergaming is effective in increasing EE, PA and METs. 4/18 studies found no significant differences across groups in PA, BMI and weight loss. 1 RCT reported that exergaming increased self-reported PA, but not objectively measured PA. Large variability in sample sizes, intervention duration and exergaming session frequency. Study design quality ranged from 3-10 for home-based studies, with 7 high quality studies above the median score (5.5 on 10) (note: only home base setting results are reported here).	No

**Lu et al., 2013[119]	≤18 yrs. (all participants were 7-18 years) 0-18 years old	Oct 2010 to Mar 2013 and Apr 2011	14 (representing 14 unique interventions or projects)	PubMed, EBSCO, IEEE/ACM, Google Scholar, Health Game Research Database, manual search of article reference lists, email inquiries to authors.	Systematic ** van't Riet et al., 2014	Yes	Effect of health videogame interventions on obesity or BMI, BMI z score/ %tile/SDS, triceps skinfold, thickness, waist circumference, waist-to-hip/ height ratio, or bioelectrical impedance analysis.	N/A	4 studies reported differences in obesity outcomes among overweight or obese children; one found a significant reduction in the first half of the intervention, and another among girls only. No change in obesity outcomes in 8 studies. 13 studies found significant change in duration of vigorous PA. Positive outcomes related to obesity were observed in about 40% of studies, all of which targeted overweight or obese participants.	Social Cognitive Theory; Self-Determination Theory; Behavioural Inoculation Theory; Self-Care Deficit Nursing Theory
Okorodudu, 2014[27,181]	All ages	2008-2013	Not reported (possibly 7 studies on exergame use)	Pub Med, Google scholar	Systematic	No	Weight reduction interventions using exergaming	Weight reduction strategies using cell phones and the internet	Exergaming elicits light to moderate PA but does not help attain guidelines RCTs report weight loss among overweight/obese African-American adolescents Exergaming increased light-to-moderate intensity PA acutely but did not contribute to recommended guideline goal. Reported weight loss among overweight and obese African American adolescents who used co-operative exergaming vs. competitive gaming and control group. Higher HR, oxygen uptake and EE in exergaming vs. sedentary games.	No
Lambogliia et al., 2013[182]	6-–15 years old	Jan 2008 to Apr 2012	9	SciELO, LILACS, PubMed, EBSCO, PubMed, Ebsco, Science Direct.	Systematic	Yes, somewhat (quality of selected studies determined based on impact factor of journal), all of	Body composition	Cardiorespiratory function, SB, Exergaming effects on PA, EE, health behaviour, EE, musculoskeletal	Exergaming increased PA levels, EE, maximal oxygen uptake, HR, and % PA engaged Exergaming increased PA level, EE and cardiorespiratory function. Exergaming reduced body fat and	No

						which ranked above B3 in the Qualis System (CAPES)		system, cardiovascular system.	sedentary behaviour screen time	
van't Riet et al., 2014[171] *Continuation of Lu et al, 2013[119]	All ages (reported results for youth only)	Not reported	5 (for youth)	Not reported (this review adds effect sizes to 5 studies in Lu 2013)	Meta-analysis	Yes - Cochrane Collaborations risk of bias tool	BMI	No	Small, non-significant, positive effect of exergaming in children and adolescents' BMI: Hedges g=0.20 (95% CI: 0.04, 0.37). Small, non-significant, positive composite-effect of exergaming in children and adolescents' BMI: Hedges g=0.20 (95% CI: -0.08, 0.48). No significant Q statistic [Q (4) =7.46, P=0.11] indicating limited heterogeneity.	No
Daley, 2009[145]	≤18 years	Searched on Dec 9, 2008	17 (14 descriptive studies, 3 intervention studies)	PubMed, bibliographies of identified studies and reviews	Literature review	No	BMI, waist circumference, skinfold thickness	Health outcomes/ energy demands, PA, sedentary behaviour	Some exergames illicit moderate PA RCTs have mixed results. EE costs of games vary considerably Youth engage in exergaming for short periods only (<10 min/bout). Exergaming produces greater EE than sedentary gaming and rest, but may not be appropriate substitutes for traditional sports and PA. Improvements in some health outcomes in two trials.	No

SB: Sedentary behaviour; PA: Physical activity; EE: Energy expenditure; HR: Heart rate; RPE: rate of perceived exertion; BMI: Body Mass Index; SES: Socioeconomic status; METS: metabolic equivalents

2.3.4 Quality of reviews

Agreement between EO and HG on the quality (total score) of each review was acceptable (ICC = 0.872). The reviews included were generally of medium quality with an M (SD) quality score of 24.4 (5.2) (range 8 to 31). Overall the reviews scored well on criteria related to the study characteristics, study information, the summaries and the study conclusions; they scored poorly on the quality scoring, eligibility criteria, duplicates, funding and conflict

information; and they scored moderately on the title, limitations, abstract summary, search criteria and selections criteria. Thirteen reviews scored low on the item assessing if the quality of the studies included was assessed using a standardized approach. Eligibility criteria were not always explicit, and 20 reviews scored "somewhat" only for that category. Eight reviews did not mention how duplicates were dealt with or if there were at least two independent reviewers. Most reviews (n=23) scored high on their summary tables detailing the strength of evidence for the primary outcomes and considering their relevance to key groups. All but three reviews scored high on the study characteristics component. Conclusions and summaries were generally scored high because most authors provided an interpretation of the results in the context of other evidence and described implications for future research. Thirteen reviews did not declare sources of funding or conflict (although this could relate to journal requirements).

2.3.5 Recommendations

The most frequent research-related recommendations (Table 4) were to conduct longitudinal studies, RCTs and home-based studies of longer duration and higher quality, to investigate how to encourage exergaming sustainability and identify the determinants of compliance (n=22); Explore potential moderators (age, sex, socioeconomic status, weight status, type of game) and outcomes such as enjoyment, goals and motivation (n=12); to examine whether exergaming can promote PA in select subgroups; (n =9); to investigate outcomes such as enjoyment, goals and motivation (n=10); to incorporate more precise measures of body composition (e.g. lean body mass, percent body fat), physical fitness as outcomes and use common metrics that can be compared across games and studies (n=6) and finally to use larger sample sizes, control groups and longer follow-up times (n=6).

Recommendations related to intervention development focused on how exergaming can be better incorporated into PA interventions. The most frequently mentioned ways to accomplish this included: by encouraging competition and group play (including using the Internet) (n=12); by including components that foster social support (n=9); by using lower or whole body exergames because they expend more energy (n=6); by providing choices by making a variety of different games available and regularly changing goals (n=3). Other less frequently mentioned ways included by: fostering experience; focusing on enjoyment first with weight loss as secondary; using the latest technology; having a coach; using exergaming in addition to regular

PA and discouraging sedentary behaviour during the intervention; and by including transferability components that illustrate how skills and coordination acquired in exergaming can be transferred to outdoor or real life sports (i.e., have an interactive and transferable intervention). Finally, four reviews suggested the exergaming intervention research, whether intervention-, laboratory- or population-based, should incorporate theory or conceptual frameworks such as the self-determination theory, game flow model or goal-setting theory to guide the research[25,26,169,170] and potentially increase the success of interventions and mobile exergaming and Augmented Reality APPs.

The most frequently mentioned *game design* recommendation was to incorporate immersive narratives into exergames (which are in part, the allure of non-active videogames) to increase interest and sustainability (n=7). There were also recommendations for greater engagement and collaboration among participants, researchers, and the game designing community to assure that future exergames incorporate user preferences, include features that improve the cognitive benefits of exergaming, integrate behavioural theories in the design, as well as have increasing PA as an objective when designing game features.

Table 4. Recommendations for future research and intervention development in review studies (n=25)

Recommendation	Reference	Frequency
Participant issues		
Examine whether exergaming affects subgroups (BMI, sex, age) differently for immediate and habitual PA outcomes.	169	1
Examine whether exergaming can be used to promote PA in select subgroups	27,29,31,168,172,178,183, 184	9
Study impact of entire activity profile on SB, BMI, weight changes	29,173,175,177,180	4
Explore potential moderators (age, sex, socioeconomic status, weight status, type of game) and outcomes such as enjoyment, goals and motivation	25,29,62,169,171,172,175, 177,179,180,183,184	12
Study design and methods		
Higher quality longitudinal studies, RCTs and home-based studies of longer duration are needed. Investigate how to make exergaming sustainable. Identify determinants of compliance	25,26,29,31,62,119,145,16 8,170,172,173,175-181,183-186	16
Collaborative research among developmental and cognitive psychologists, kinesiologists, behavioural medical researchers, and game designers.	15,62,119,179,185	5
Study potential risks of exergaming (injuries, reduced sleep, addiction, aggressiveness)	29,83,145	3
Participant recruitment (to RCTs) should be more systematic to limit selection bias	170	1
Study updated technologies. Include chronic exergaming, gaming systems/accurate sensors	15,31,172,181,185	5
Use larger sample sizes, control groups and longer follow-up times	119,168,175,176,183,184	6
Explore exergaming as a gateway to organized sports. Develop games that mimic real life PA	31,168,172,179	4
Use exergames with other interventions (in classroom, in conjunction with other PA)	25,179,184	3
Conduct research on motivational theoretical models for games	26 179	2
Displacement effect/behaviour compensation	145,173,184	3
Compare games and consoles	83,168,175,183,184	5
Compare exergaming to regular PA and laboratory-based exercise	168,183,184	3
Appropriate strategies to evaluate games and deliver them in ways that are reproducible	179	1
Studies examining exergaming in naturalistic settings	183	1
Analysis		

Investigate extent to which exergaming promotes learning and maintenance of new movement skills and cognitive skills, and improve understanding of the impact of exercise on bodies	184	1
Explore play, performance, simulation, appropriation, multitasking, distributed cognition, collective intelligence, judgment, transmedia navigation, networking and negotiation	25	1
Identify how exergaming influences children's behaviour	175	1
Examine opportunity cost	27,173,177	3
Identify barriers that impede exergaming	179	1
Conduct needs assessments to determine which game factors are fun, to improve sustainability	179	1
Examine the effectiveness of using multi- vs. single-player modes in school-/community-based settings as well as online settings	184	1
Conduct more meta-analyses, use generalized linear mixed models	28,171,184	3
Determinants of children use exergaming to replace screen time or traditional sports/PA	184 183	2
Measurement		
Incorporate precise measures of body composition (e.g. lean body mass, % body fat), physical fitness as outcomes, use common metrics that can be compared across games and studies	29,83,170,174,179,184	6
Examine effect of exergaming play on muscle or bone strength	28	1
Measure energy intake while exergaming compared to SB	83,173,186	3
Study reliability and validity of self-report measures, focus on using direct and indirect measures to assess total exergaming use	69,180 83	3
Examine inconsistent findings on MET values using indirect calorimetry vs. accelerometry	169	1
Exergaming interventions		
Offer variety (many games)	170,176,183	3
Use mobile exergaming	25,26	2
Include parental encouragement	176	1
Use behavioural theories (goal setting)	25,26,169,170	4
Engage participants in interventions and game design, user preference	29,145,179	3
Encourage players to perform at their own abilities	172,176	2
Constant feedback to players (physiological measures)	172	1
Offer constant incentives	172	1
Encourage competition and group play (including using the internet)	15,28,29,172,175,176,179, 180,184-186 170	12
Encourage social support (including using the internet)	15,29,169,172,175,179,181 ,185 , 170	9
Give guidelines (prescriptions), have a trainer, more structure	29,172,185,186	4
Use lower or whole body exergames in interventions	29,62,172,175,176,184	6
Play intensity and design need to be considered (equal opportunity for all skill levels)	27,172	2
Improving quality of interventions		
Conduct process evaluation of exergaming to ensure intervention fidelity	183	1
Interventions should include many components (ex: include diet component)	169	1
Start exergaming interventions in early childhood (preschoolers)	184	1
Determine compliance rate and identify determinants of compliance	170	1
Reduce participant bias in studies (systematic recruitment)	170	1
Require log/check ins and frequent playing (minimum of one hour/weekly for 10–16 weeks)	177	1
Improve intervention fidelity in RCTs	145,183,184	3
Conduct larger, methodologically sound intervention trials	69	1
Professionals should use exergaming interventions as an option to promote PA in youth	183	1
Exergame design		
Warm up and cool down in game play	172	1
Have music in games (make it appropriate)	172	1
Incorporate immersive narratives (stories)	15,29,119,172,179,185,186	7
Design games to increase PA	176	1
Include Avatars in games	26	1
Design PA promotion exergaming guided by behavior change theories	119,186	2
Design with sustainability in mind	172,177	2
Design games that promote the most PA	69,170,183	3

SB: Sedentary behaviour; PA: Physical activity; EE: Energy expenditure; HR: Heart rate; RPE: rate of perceived exertion; BMI: Body Mass Index; SES: Socioeconomic status

2.4 DISCUSSION

This narrative overview on exergaming in youth and adults sought to synthesize existing knowledge on the associations between exergaming and (i) PA, sedentary behaviour and EE and (ii) body composition and weight. We also highlight gaps in the literature to guide future exergaming research, the development of exergaming interventions and game design.

The reviews support that exergaming elicits more EE than traditional videogames,[62,170,171,183] and that some games, depending on the intensity with which they are played, can elicit moderate to vigorous PA. There was a wide consensus on the need to move beyond laboratory-based exergaming research to more in-depth and higher quality experimental studies in naturalistic settings. The area of mobile exergaming and Augmented Reality APPs requires more attention. There was only one review that focused specifically on mobile exergaming and Augmented Reality APPs;[26] most others did not mention them. Considering the popularity of APPs such as Pokémon Go, mobile exergaming and Augmented Reality APPs should be considered in future exergaming research and used in exergaming interventions. Many would argue that consoles are becoming obsolete and that portable gaming is where gaming research should be focused.[187]

Most reviews provided a positive take-home message, that exergaming can generate favourable effects but that it should be incorporated into a more comprehensive intervention that aims to increase PA and decrease sedentary behaviour. However, recommendations should be specific (not just "more research") and supported by the evidence.

The reviews suggested that exergaming should not replace traditional PA, but that it can be used in addition to PA and/or to replace sedentary behaviour. However higher quality research is needed to provide stronger evidence and assure that exergames attain their full potential. Several reviews[145,173] questioned the potential contribution of exergaming to PA activity levels in youth, including one review which was used to support the position of Active Healthy Kids Canada on Active Videogames for Children and Youth. The authors stated that they do not recommend exergaming as a strategy to help youth be more physically active.[160] However, most reviews indicated that it is too early to develop evidence-based recommendations. One review which questioned the potential of exergaming acknowledged that: "Electronic entertainment has established itself as an integral part of life in the 21st century, so we may have to consider ways in which we can work with it rather than against it".[145] It is

recommended that research into the potential of exergaming continue, and that recommendations be based on longitudinal and higher quality research.

Finally, although few reviews discussed it, mobile exergaming\ Augmented Reality gaming is becoming increasingly popular and will likely render exergaming research more compelling. Mobile exergames\ Augmented Reality for global positioning system (GPS)-enabled smartphones and mini-tablets are gaining popularity.[152] These can be played outdoors in the open air. This type of mobile\Augmented Reality gaming may increase the popularity of exergaming because of the appeal of sharing through online social networks, and by using gamification principles.[152] With mobile\ Augmented Reality exergaming, the real world becomes the 'game map' or playground in these games, and players can discover and learn about new places and new geographies while obtaining health benefits through movement.[152]

2.4.1 Limitations

Limitations of this narrative overview include that the research to date primarily concerns commercially available exergames although other types of exergames are available including outdoor mobile/Augmented Reality games and exergaming gym equipment. Games which involve stories (which could serve as a powerful motivating strategy to engage players long-term) and mobile/Augmented Reality exergames were not common among the exergames covered in this review,[188-190] although in-depth analysis of games specifically designed for research interventions is warranted. We retained only English and French language reviews, and we excluded qualitative studies. In addition, although our outcomes of interest included PA, body composition and health, many reviews did not focus on a single outcome. It was difficult to categorize some reviews since they aligned with several outcomes of interest. A review of meta-analyses was not feasible due to high variability across studies in study design, outcomes investigated, samples and measurement instruments. Finally, narrative reviews are limited by the subjectivity of the analysis.[183]

2.5 CONCLUSION

Exergaming increases EE compared to sedentary behaviour and may decrease time spent in sedentary behaviour. However, it is unclear if exergaming increases PA or changes body composition. Future research should investigate whether enjoyment of exergaming motivates

sustained participation. The reasons for the popularity of traditional videogame-playing should be exploited to improve exergaming interventions. There are no population-based studies of exergaming in naturalistic settings and results on sustainability in extant studies are mixed. Therefore, increased understanding of who will not sustain exergaming are key issues that need to be addressed. Surveillance is needed to monitor trends and assess the prevalence of exergaming at a population level. Testing exergaming in more (diverse) populations including young and older adults should be a priority. Work should be undertaken to develop and test exergaming guidelines including how to incorporate exergaming into everyday life. Research is needed to determine how to maximize the potential health benefits of exergaming. Future research should include pertinent recommendations from previous research to improve exergaming interventions and to design games that are sustainable and increase PA. Finally, future reviews on the exergaming literature should use standard review criteria to ensure high quality reviews and include specific recommendations for future research. The association between type of exergame and EE is well-established and future reviews should examine longitudinal studies of exergaming.

TRANSITION TO STUDY 2

The goal of Study 1 was to summarize evidence from systematic reviews and meta-analyses on the associations between exergaming and: (i) PA, sedentary behaviour or EE; and (ii) body composition, BMI or weight outcomes among persons under age 30; as well as: (iii) to summarize recommendations in the articles retained. This updated synthesis included quality assessments of the articles included, which provides critical information for future research and practice on the value of the evidence.

Our review was extensive and highlighted numerous gaps in the literature on exergaming that need to be addressed. Several of these gaps will be addressed in Study 2 (and Study 3). One important gap is that few population-based studies investigate exergaming in naturalistic settings since most studies were laboratory-based or intervention studies. Much can be learned from observational studies and especially longitudinal studies in population-based samples, including whether exergaming is a sustainable behaviour over time, which is key in attaining health benefits.

The current literature on the sustainability of exergaming is mixed. Although exergaming may increase PA (among other health benefits) in intervention studies, it is not clear whether the behaviour will be sustained post-intervention. Therefore, increased understanding of the characteristics of persons who sustain exergaming and why is key. In fact, one of the most cited recommendations from our review of reviews was to conduct higher quality longitudinal studies, RCTs and home-based studies of longer duration and to investigations on how to make exergaming sustainable. Our review also highlighted that most of the exergaming and PA research was not grounded in motivation theory, which we recommended for future studies so that the research is guided by theory. In addition, surveillance is needed to monitor trends and assess the prevalence of exergaming at a population level.

Thus, the objectives of Study 2 were to examine the frequency of sustained exergaming and to identify factors associated with sustained exergaming in a population-based sample over 2-3 years using the self-determination theory as guidance. To our knowledge, this is the first longitudinal population-based study in which correlates and predictors of exergaming were studied.

CHAPTER 3

STUDY 2

FREQUENCY AND FACTORS ASSOCIATED WITH SUSTAINED EXERGAMING IN ADOLESCENTS

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ABSTRACT

Objective. Exergaming is technology-driven physical activity such as videogame play, which requires participants to be physically active to play the game. Exergaming is emerging as a practical approach to increase physical activity and decrease sedentary behaviour in youth, but little is known about sustained exergaming. The objectives of this study were to describe the frequency of sustained exergaming as well as factors associated with sustained exergaming. **Methods.** Data were available in AdoQuest (2005-11), a longitudinal investigation of 1843 grade 5 students in Montréal, Canada. This analysis used data from grade 9 (2008-09) and 11 (2010-11). Participants at T1 (mean age 14 (0.8) years) who reported past-week exergaming (n = 186, 19.1% of AdoQuest sample), completed mailed self-report questionnaires at T2 (mean age 16 (0.8) years). Independent socio-demographic, psychological and behavioural correlates (from T2)/predictors (from T1 or earlier) were identified using multivariable logistic regression. **Results.** Of 186 exergamers at T1, 81 (44%) reported exergaming at T2. Being female and having higher introjected regulation (i.e., a type of PA motivation indicative of internalization of PA as a behaviour) were independent correlates. None of the predictors investigated were associated with sustained exergaming. **Conclusions.** Almost 44% of grade 9 exergamers sustained for 2-3 years. Exergaming may be a practical approach to help adolescents maintain PA during adolescence. Sex and PA motivation may be important in the sustainability of exergaming, and exergaming interventions may need to these aspects in the development and implementation of exergaming interventions.

3.1 INTRODUCTION

Only few of Canadian youth meet current PA recommendations (about 40% of Canadian children and youth aged 5 to 17 years meet the recommended targets for PA in 2016-17).[6,10] Further, they spend up to nine hours daily sitting, usually in screen-time pursuits.[10,33] Youth who do not attain PA recommendations are unlikely to benefit from the positive effects of PA on health,[2,131] and sedentary youth may experience a wide range of negative physical and mental health issues.[191] Effective programs and public health policy are needed to address these issues because co-occurrence of low PA and high sedentary time contributes to childhood obesity and its numerous deleterious health sequelae.[66,192-194]

Despite possible negative impacts on health, screens are an indisputable reality in today's increasingly high-tech world.[56] Underscoring its popularity, 83% of U.S. youth ages 8-18 years have a traditional videogame console at home, and many of these consoles having add-on capacity for exergaming (i.e., videogames that are also a form of exercise) equipment. In addition, approximately 50% of adolescents own smartphones, which can download apps for mobile exergaming.[195] Many smartphone apps are free or low-cost, making exergaming and augmented reality (i.e., a real-world view of the environment which is "augmented" by computer-generated input) highly accessible to youth.

In 2010, nearly 40% of U.S. students in grades 9-12 exergamed at least one day per week;[149] 25% of Canadian youth ages 15-18 reported exergaming in the past week;[148] and up to 20% of young adults exergamed 1-3 times per month or more.[150] Leveraging benefit from screen fervour by incorporating PA into videogaming and by designing exergames[15,31,67,168] that are available, appealing and accessible, holds promise in terms of increasing PA and reducing sedentary time[15,31,67,168] Exergaming may be a healthier pastime than traditional videogames, because they elicit more EE[60-62] and they may improve physical fitness, body composition and cognitive health.[119,168,177,179] The effect of exergaming on reducing sedentary behaviour has also been studied, but to a much lesser extent.[76] Overall the data suggest that exergaming may be a viable method to increase PA or change body composition and improve mental health, and it represents an improvement in EE over sedentary behaviour.[15,24,31,168]

There are important methodological challenges in the current literature evaluating exergaming. Many intervention studies report high attrition. Short intervention periods (i.e., usually 6- or 12-weeks with no follow-up post-intervention) may hinder detection of longer-term

effects,[83,179,184] and most studies are performed under controlled conditions that may not apply to "real-life" settings. For example, a small pilot study that provided African-American and Hispanic children with access to exergaming at home and during an after-school program, indicated that fitness improved after 12 weeks.[196] However, 42% of participants lost interest in exergaming within 3 months, so that use may have related partly to the novelty of the consoles. In addition, the novelty of exergaming APPs on smartphones is unknown but hypothesized to be short lived. This suggests that improving understanding of PA motivation pertaining to exergaming and sustained exergaming is needed.

To inform the development of exergaming interventions that have the potential to be sustained, evidence is needed on the determinants of sustained exergaming in naturalistic settings. While O'Loughlin et al. (2012)[18] reported that exergamers were more likely to be girls, to play non-active videogames, to watch TV ≥ 2h/day, to report weight-related stress, and to be non-smokers, no reports to date describe factors associated with sustained exergaming in "real world" contexts.

Sustained enjoyment of exergaming may contribute to increases in PA intensity, possibly affecting adiposity[197] Exergaming may increase motivation through increases in self-efficacy,[198] enjoyment,[199] socialization,[197,200,201] internalization of PA,[102,116] cooperation and competitiveness[70,71,198] Lam et al. (2011)[92] found that, given a choice, youth selected exergames over non-active videogames. Osorio et al. (2014)[116] compared the motivations that encouraged participation in three contexts (i.e., exercise, computer games, exergaming) and found that enjoyment and feeling better after a session, as well as participating in a social context are key factors that encourage exergaming, in addition to exercise and computer games. Participation in exergaming is also encouraged by perceptions of performing mild exercise while playing videogames.[116] One study examined bouts of high intensity interval training and found that virtual reality-exergaming is an effective intervention to increase enjoyment during a single bout of high intensity interval training in untrained individuals.[48] Glen et al. (2017)[49] found that exergaming increased vigorous PA using an exercise bike enhanced by virtual reality compared to using the bike without virtual reality, and that findings support the use of exergaming as a strategy to encourage exercise. Participants chose to work harder physiologically, but reported more positive psychological responses including motivation, pleasure and dissociation during and following the exercise.[49] Marker et al. (2015)[91] reported that competitive play increased EE

in short exergaming bouts and that cooperative exergaming increased motivation, promoted continued play, enhanced self-efficacy, and increased pro-social behaviours. Finally, Dos Santos et al. (2016)[202] also found that youth who underwent a 7-week exergaming intervention were more likely to be involved in a new sport during a 1 and 2 year follow-up period. Appendix B describes exergaming and motivation more fully.

The objectives of this study were to: (i) describe the sustainability of exergaming over two years in a population-based sample of adolescents; and (ii) to identify factors associated with sustained exergaming.

3.2 METHODS

Data were drawn from AdoQuest I (2005-11), a 6-year longitudinal study of 5th grade students (*n* = 1,843 age 10-11 years at baseline), which investigated the natural course of the co-occurrence of health-compromising behaviours such as smoking, sedentary behaviour and substance use in youth.[18] A random sample of French-language elementary schools with >90 students in 5th grade was recruited in the greater Montreal area. To balance representation of students in high, middle and low socioeconomic status (SES), schools were stratified into groupings defined by tertile of a school deprivation indicator based on maternal education, parental employment, and a measure of low family income that accounts for family size and area of residence.[203] An equal number of schools were selected into each grouping, and 10 schools in the first, 10 in the second and 9 in the third grouping (72.5% of schools invited) agreed to participate; students were recruited from all 5th grade classes in the 29 participating schools. Characteristics of the AdoQuest sample were comparable to those of two provincially representative samples of similarly-aged Québec youth.[204] Parents completed mailed self-report questionnaires in 2006-07 and again in 2008-09. Participants provided assent and their parents/guardians provided informed consent. The study received approval from the ethics and protection review boards of Concordia University and the Centre de Recherche du Centre Hospitalier de l'Université de Montréal.

Sustainability of exergaming over two years was investigated using data collected in the fall and winter of 2008-09 (T1) when participants were in grade 8 or 9 (age 12-14 years), and two years later in the fall and winter of 2010-11 (T2) when participants were in grade 9-11 (age 14-19 years). Our research focus was to describe sustained exergamers and not those who started

exergaming, which is a worthwhile research endeavour but not the focus of the current study. Data on exergaming and potential correlates and predictors were collected in mailed self-report questionnaires at both T1 and T2. Most questions used in AdoQuest were drawn from ongoing surveys and studies of youth including the Canadian Youth Smoking Survey[205] and the Nicotine Dependence in Teens Study.[206]

3.3.1 Study variables

Sustained exergaming - At T1, participants were asked: How many hours a day do you play active videogames? Response choices included 0<1, ≥1-2, 2-3, 3-4 or ≥5 hrs/day. Participants were categorized as exergamers if they responded ≥1 hrs/day. At T2, participants were asked: "Do you play active videogames (ex: Wii Fit®, Dance Dance Revolution®)?" (yes, no). Participants were categorized into one of two groups based on their responses to these two questions. "Sustained exergamers" included participants who reported exergaming at T1 and T2; those who "stopped exergaming" reported exergaming at T1 but not T2. Never exergamers and those who began exergaming between T1 and T2 were not included in the analysis.

Frequency, timing and intensity of exergaming - At T2, questions on exergaming were included based on the International Physical Activity Questionnaire, a short, self-administered questionnaire used in cross-national monitoring of usual weekly PA in youth and adults. The IPAQ demonstrates reliability as well as validity against accelerometer.[207] Specifically, exergamers were asked: (i) How many days a week do you play active videogames? (1 - 7 days); (ii) How many minutes (on average) do you play each time? (open-ended); and (iii) physical effort during play (light, moderate, vigorous).

Potential correlates and predictors of sustained exergaming were selected based on factors known to be associated with PA or exergaming in adolescence,[18,126] and on the availability of data in AdoQuest. Potential correlates measured at T2 included socio-demographic characteristics (i.e., age, sex, mother university-educated, annual household income, currently employed), lifestyle behaviours (i.e., moderate-to-vigorous PA/wk., meets moderate-to-vigorous PA guidelines, binge drank in the past year, used marijuana in the past year, hours TV/day, hours computer/day, hours non-active videogames/day), weight-related indicators (BMI ($kg/m^{2)}$, stress about weight, perceived weight status, trying to lose weight, body-related guilt, body-related shame), PA motivation and depressive symptoms.

Potential predictors measured prior to or at T1 included lifestyle behaviours (i.e., level of PA, ever smoked cigarettes, binge drank, marijuana use, hours TV/ per day, hours computer/day, hours non-active videogames/day, hours sedentary behaviour/day), weight-related indicators (i.e., BMI, stress about weight, perceived weight too heavy, trying to lose weight), depressive symptoms and the Pediatric Daytime Sleepiness Scale.

Appendix F describes each variable in detail including response options, coding for analysis, and Cronbach's alpha for scales.

3.3.2 Data Analysis

Descriptive statistics were used to compare participants who did and did not sustain exergaming. We considered the investigation of each potential correlate or predictor as an independent study that addressed a specific hypothesis so that only three statistical tests (i.e., univariate, partially-adjusted model, fully-adjusted model) were performed for each potential correlate.[208] Potential confounders were retained in the model if they were correlated with the potential correlate/predictor and outcome at $r > 0.20$.[209,210] Three logistic regression models including: (i) a univariate model examining the unadjusted association between the potential correlate/predictor and outcome with no covariates; (ii) a partially-adjusted model accounting for age and sex; and (iii) a fully-adjusted model including age, sex and (other) potential confounders. Data were analyzed using SPSS version 20.0 (released 2011, SPSS Statistics for Windows; IBM Corp., Armonk, NY). All statistical tests were two-sided, with the significance level set at 0.05.

3.4 RESULTS

Data on exergaming were collected in AdoQuest for the first time in grade 9 in 2008-9. Of 1801 grade 5 participants at AdoQuest inception in 2005-6, 1233 (68.4%) completed questionnaires at T1 in grade 9, and 16.5% of the 1233 participants reported exergaming. At T2 in grade 11, 1243 (69.0% of 1801) completed questionnaires, and 24% of the 1243 participants reported exergaming. A total of 974 participants (54% of 1801) completed questionnaires at both T1 and T2. Of the 974, 63% never exergamed, 18% began exergaming between T1 and T2, and 8% and 11% sustained and stopped exergaming, respectively. The total number of exergamers at T1 who also provided data on exergaming at T2 was 186 (19.1% of 974) and these participants constituted the analytic sample.

Table 5 compares the characteristics of the 186 participants retained in the analytic sample with those of the 59 participants who exergamed at T1 but were missing data on exergaming at T2. There were no statistically significant differences between the two groups, although 49.4% of those retained reported taking action to change their weight compared to 35.8% of those not retained (p = 0.086).

Table 5. Comparison of baseline characteristics of exergamers retained (n=186) and not retained (n=59) in the analytic sample, AdoQuest, 2005-12

Variable	Retained	Not retained[a]	*P* value
Age (years) at baseline, mean (SD)	10.8 (0.5)	10.7 (0.5)	0.52
Male, n (%)	90 (48.6)	32 (53.4)	0.52
Mother university-educated, n (%)	56 (30.1)	15 (25.5)	0.13
French-speaking, n (%)	165 (88.6)	51 (86.4)	0.66
Self-esteem, mean (SD)	2.0 (0.7)	2.0 (0.7)	0.99
Depressive symptoms, mean (SD)	2.0 (0.7)	2.0 (0.6)	0.87
School connectedness, mean (SD)	2.3 (1.0)	2.3 (0.9)	0.97
Taking action to change weight, n (%)	92 (49.4)	21 (35.8)	0.08
TV ≥3 hours per day, n (%)	70 (37.6)	23 (39.7)	0.78
Perceived academic performance, n (%) above average	72 (38.8)	27 (45.5)	0.35

[a]Exergamers at T1 without exergaming data at T2.

The mean (SD) age of participants in the analytic sample was 16.7 (0.5) years at T2, 42% were boys, 93% were Caucasian, 76% were in grade 11, 47% were employed full or part-time, and 33% had university-educated mothers. The mean (SD) BMI was 23.6 (5.0) in boys and 22.2 (4.1) in girls. Thirty percent of participants' parents reported an annual household income ≥ $100 000 (CAN).

Of the 186 participants retained in the analytic sample, 81 (43.6%) sustained exergaming (i.e., reported exergaming at T1 and T2). At T2, sustained exergamers (n=81) exergamed on a mean (SD) of 1.9 (1.4) days per week, for 49.0 (33.8) minutes per bout on average. Thirty-five percent of sustained exergamers reported that they exergamed at light intensity, 42% exergamed at moderate intensity, and 23% exergamed at vigorous intensity.

In univariate analyses of potential correlates measured at T2 (Table 6), girls were twice as likely to sustain exergaming as boys. With each unit increase in depressive symptoms, the odds of sustained exergaming increased by 40%. Similarly, the odds of sustained exergaming were higher in participants with higher levels of introjected, identified or intrinsic regulation. Finally, the odds of exergaming increased by 30% with each unit increase in body-related guilt. In partially-adjusted models, girls were more likely to sustain exergaming, and for each unit increase in introjected regulation, there was a 60% increase in the odds of sustained exergaming.

Finally, in fully-adjusted models, the only variable retained was introjected regulation (OR (95% CI) 1.8 (1.1, 3.2)).

Table 6. Odds ratios (OR) and 95% confidence intervals (CI) for the association between potential correlates and sustained exergaming, AdoQuest 2005-12 (n=186)

Indicators[a]	n (%)	Sustained exergaming[b] n (%)	OR_{crude} (95% CI)	Model adjusted for age and sex OR_{adj} (95% CI)	Fully adjusted model OR_{adj} (95% CI)	Covariate(s) included in fully adjusted model
Sociodemographic indicators						
Age (years)[c]						
14.39-16.63	60 (32.3)	25 (41.7)	1.3 (0.8-2.1)[d]	1.2 (0.7-2.0)	1.2 (0.7-2.0)	Sex
16.64-16.98	59 (31.7)	21 (40.7)				
16.99-19.86	59 (31.7)	28 (47.5)				
Sex						
Boys	83 (44.6)	30 (34.9)	ref	ref	ref	Age, moderate-to-vigorous PA, nonactive videogames
Girls	103 (55.4)	51 (50.5)	2.0 (1.1-3.4)	1.9 (1.0-3.4)	1.6 (0.8-3.3)	
Mother university-educated						
Yes	49 (26.3)	23 (46.9)	ref	ref	ref	Age, sex, income
No	108 (58.1)	45 (41.7)	0.8 (0.4-1.6)	0.8 (0.4-1.)	0.9 (0.4-2.0)	
Income, CAN $						
<100K	84 (45.2)	33 (38.9)	ref	ref	ref	Age, sex, mother's education
≥100K	60 (32.3)	28 (46.9)	1.4 (0.7-3.0)	1.4 (0.7-3.0)	1.5 (0.7-3.2)	
Employed (participant)						
Yes	78 (42.0)	34 (43.6)	ref	ref	ref	Age, sex
No	101 (54.3)	43 (42.6)	1.0 (0.5-1.7)	1.0 (0.6-1.9)	1.0 (0.6-1.9)	Age, sex
Lifestyle behaviours						
Moderate-to-Vigorous PA min/week[c]						
0-105	59 (32.8)	21 (35.6)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	Age, sex, identified regulation
106-295	57 (30.6)	30 (52.6)				
≥295	64 (34.4)	28 (43.8)				
Meets Moderate-to-Vigorous PA guidelines						
Yes	42 (22.6)	16 (38.1)	ref	ref	ref	Age, sex, intrinsic, body shame
No	138 (74.2)	63 (45.7)	1.4 (0.7-2.8)	1.1 (0.5-2.3)	1.3 (1.0-1.6)	
Binge drank past year						
Yes	82 (44.1)	37(45.1)	ref	ref	ref	Age, sex, marijuana use, intrinsic regulation
No	94 (50.5)	39(41.5)	0.9 (0.5-1.6)	0.9 (0.5-1.6)	1.2 (0.6-2.4)	
Used marijuana past year						
Yes	141 (75.8)	71 (50.0)	ref	ref	ref	Age, sex, binge drinking, smoked cigarettes
No	34 (18.3)	14.2 (41.8)	1.0 (0.8-1.3)	0.7 (0.3-1.6)	0.4 (0.1-1.0)	
Hours TV per day[c]						
≥0 <1	42 (22.6)	19 (45.2)	1.0 (0.8-1.4)	1.1 (0.8-1.4)	1.1 (0.8-1.5)	Age, sex, depressive symptoms
≥1 <2	78 (41.9)	31 (39.7)				
≥2	66 (35.5)	31 (47.0)				
Hours computer per day[c]						
≥0<1	38 (20.4)	15 (39.5)	1.1 (0.9-1.3)	1.1 (0.8-1.3)	1.1 (0.8-1.3)[e]	Age, sex
≥1<2	56 (30.1)	22 (39.3)				
≥2	92 (49.5)	44 (47.8)				
Hours nonactive videogames per day[c]						
0	82 (44.1)	32 (39.0)	1.0 (0.8-1.3)	1.0 (0.9-1.4)	1.0 (0.9-1.4)[e]	Age, sex
<1	50 (26.7)	28 (56.0)				

≥1	53 (28.5)	2 1(39.6)				
Weight-related indicators						
Body mass index (BMI)[c]						
16.01-20.1	49 (26.3)	23 (46.9)	1.0 (0.9-1.0)	0.9 (0.9-1.1)	0.9 (0.8-1.0)	Age, sex, income, extrinsic motivation, body shame, body guilt
20.2-23.54	51 (27.4)	20 (39.2)				
23.55-40. 70	49 (26.3)	18 (36.7)				
Stressed about weight						
Yes	50 (26.9)	25 (50.0)	ref	ref	ref	Age, sex, depressive symptoms, weight perception, introjected regulation, external regulation, body shame, body guilt, trying to lose weight
No	129 (69.4)	52 (40.3)	0.7 (0.4-1.3)	0.8 (0.3-2.1)	0.9 (0.3-2.0)	
Perceived weight status, overweight						
Yes	49 (26.3)	23 (46.9)	ref	ref	Ref	Age, sex, BMI, introjected regulation, external regulation, body shame, body guilt, stress about weight, trying to lose weight
No	127 (68.3)	53 (41.7)	0.8 (0.2-1.6)	0.8 (0.2-1.6)	0.3 (0.1-1.3)	
Trying to lose weight						
Yes	114 (61.3)	57 (50.0)	ref	ref	Ref	Age, sex, BMI, weight perception, introjected regulation, external regulation, identified regulation, stress about weight, weight perception, body shame, body guilt
No	62 (33.3)	25 (39.5)	0.7 (0.4-1.2)	0.8 (0.4-1.4)	0.8 (0.3-1.2)	
Body-related guilt[c]						
0 ≤1.0	67 (36.0)	20 (29.9)	1.3 (1.0-1.7)	1.2 (0.9-1.7)	0.9 (0.4-2.0)	Age, sex, BMI, depressive symptoms, weight perception, extrinsic regulation, introjected regulation, identified regulation, body shame, stress about weight, trying to lose weight
>1.0 ≤2.0	52 (28.0)	26 (50.0)				
>2.0 - 5.0	58 (31.2)	29 (50.0)				
Body-related shame[c]						
0 ≤1.0	61 (32.8)	16 (26.2)	1.2 (0.9-1.7)	1.2 (0.9-1.6)	1.0 (0.4-2.3)	Age, sex, stress about weight, BMI, depressive symptoms, weight perception, extrinsic regulation, introjected regulation, body guilt, trying to lose weight
1.0 ≤2.0	59 (31.7)	31 (52.5)				
>2.0-4.8	57 (30.6)	28 (49.1)				
Physical activity motivation						
Amotivation[c]						
0 ≤1	130 (69.9)	57 (43.8)	1.3 (0.7-2.4)	1.3 (0.7-2.6)	2.0 (0.9-5.0)	Age, sex, identified regulation, intrinsic regulation, body shame
>1-4	47 (25.3)	18 (38.3)				
External[c]						
0 ≤1	113 (60.8)	46 (40.7)	1.0 (0.5-2.1)	1.1 (0.5-2.2)	0.9 (0.3-2.8)	Age, sex. BMI, depressive symptoms, stress about weight, weight perception, trying to lose weight, introjected regulation, body shame, body guilt
>1 ≤1.67	20 (10.8)	11 (55)				
1.68-3.25	44 (23.7)	18 (40.9)				
Introjected[c]						
0	67 (36.0)	21 (31.3)	1.7 (1.2-2.4)	1.6 (1.1-2.3)	1.8 (1.1-3.2)	Age, sex, depressive symptoms, weight stress,
1-1.67	46 (24.7)	20 (43.5)				

1.68-5	64 (34.4)	24 (53.1)				weight perception, external regulation, identified regulation, intrinsic regulation, trying to lose weight, body shame, body guilt
Identified[c]						
0-2.25	54 (29.0)	29 (37.0)	1.4 (1.0-1.8)	1.3 (1.0-1.8)	1.3 (0.8-2.0)	Age, sex, amotivation, introjected regulation, intrinsic motivation, regulation, body guilt, trying to lose
2.26-3.25	63 (33.9)	22 (34.9)				
3.26-5	60 (32.3)	33 (55.0)				
Intrinsic[c]						
0-1.0	56 (30.1)	19 (33.9)	1.3 (1.0-1.6)	1.3 (1.0-1.7)	1.3 (0.9-2.0)	Age, sex, Moderate-to-Vigorous PA, amotivation, identified, binge drinking, introjected regulation, body shame
1-1.67	55 (29.6)	23 (41.8)				
≥1.68	66 (35.5)	33 (50.0)				
Depressive symptoms[c]						
0-1.67	59 (31.7)	22 (37.3)	1.4 (1.0-2.0)	1.3 (0.9-1.9)	1.4 (0.8-2.2)	Age, sex, introjected regulation, external regulation, body shame, body guilt, stress about weight, TV use
1.68-2.50	66 (35.5)	25 (37.9)				
2.51-4.5	54 (29.0)	30 (55.6)				

[a]Potential correlate measured in grade 11.
[b]Continuous variables were grouped according to tertile cut-offs for descriptive purposes.
[c]Potential correlate included in the model as a continuous variable. Odds ratio indicates the increase in the probability of the outcome per 1-unit change in the correlate.
[d]: Not applicable.
[e]Partially and fully adjusted models were identical.

In univariate analyses of potential predictors (Table 7), more time spent playing non-active videogames daily was protective against sustained exergaming. Trying to lose weight was associated with an 80% increase in the odds of sustained exergaming. In partially-adjusted models controlling for sex and age, and in fully-adjusted models, none of the potential predictors were statistically significantly associated with sustained exergaming.

Table 7. Odds ratios (OR) and 95% confidence intervals (CI) for the association between potential predictors and sustained exergaming, AdoQuest, 2005-12 (n=186)

Predictors[a]	**n (%)**	**Sustained exergaming[b] n (%)**	**OR_{crude} (95% CI)**	**Model adjusted for age and sex OR_{adj} (95% CI)**	**Fully adjusted model OR_{adj} (95% CI)**	**Covariates included in fully adjusted model**
Lifestyle behaviours						
Physical activity level[c]						
1	37 (20.0)	13 (35.1)	1.0 (0.8-1.3) [e]	1.1 (0.8-1.3)	1.1 (0.8-1.3)[d]	Age, sex
2-3	107 (57.5)	50 (46.7)				
4-5	40 (21.3)	16 (40.0)				
Ever smoked cigarettes						
Yes	57 (30.7)	29 (50.9)	ref	ref	ref	Age, sex, cannabis, binge drinking, depressive symptoms, PDSS[f]
No	127 (68.3)	51 (40.2)	0.7 (0.4-1.2)	0.7 (0.4-1.3)	0.5 (0.3-1.2)	
Binge drank						

Yes	43 (26.3)	16 (37.2)	ref	ref	ref	Age, sex, cigarette, depressive symptoms, cannabis, PDSS
No	143 (76.9)	65 (45.5)	1.4 (0.7-2.8)	1.3 (0.6-2.6)	1.5 (0.6-3.8)	
Marijuana use						
Yes	21 (11.3)	9 (42.9)	ref	ref	ref	Age, sex, cig try, binge drinking, depressive symptoms
No	164 (88.2)	72 (43.9)	1.0 (0.4-2.6)	0.9 (0.4- 2.4)	1.0 (0.3-3.5)	
Hours TV per day						
≤1	20 (10.8)	9 (45.0)	1.1 (0.6-2.2)	0.8 (0.6-1.1)	0.9 (0.6-1.4)	Age, sex, computer, sedentary behaviour
≥1≤3	93 (50.0)	41 (44.1)				
>3	72 (38.8)	30 (41.7)				
Hours computer per day[c]						
≤1	31 (16.7)	11 (35.5)	1.3 (1.0-1.7)	1.4 (1.0-2.0)	1.3 (0.9-2.1)	Age, sex, depressive symptoms, videogames, TV, sedentary behaviour
≥1≤3	75 (40.3)	29 (38.7)				
>3	79(42.5)	41 (51.9)				
Hours nonactive videogames per day[c]						
≤1	107 (57.5)	54 (50.5)	0.6 (0.5-1.0)	0.8 (0.5-1.3)	0.8 (0.4-1.3)	Age, sex, computer, sedentary behaviour
>1	73 (39.2)	26 (35.6)				
Hours sedentary behaviour per day[c]						
0-9.5	60 (32.3)	23 (38.3)	1.1 (1.0-1.2)	1.0 (1.0-1.1)	1.0 (0.9-1.2)	Age, sex, TV, computer, videogames
9.6-11.5	52 (27.4)	24 (46.2)				
>11.5	61 (37.8)	30 (49.2)				
Weight-related indicators						
BMI[c,g]						
13.7-19.2	35 (18.8)	17 (48.6)	1.0 (0.9-1.1)	1.1 (1.0-1.2)	1.1 (1.0-1.2)	Age, sex, trying to lose weight, videogames, perceived weight, stress about weight, sedentary behaviour
19.3-22.6	35 (18.8)	14 (40.0)				
≥22.7	36 (19.4)	11 (30.6)				
Stress about weight						
Yes	80 (43.0)	40 (50.0)	ref	ref	ref	Age, sex, depressive symptoms, trying to lose weight, perceived weight, PDSS, BMI
No	105 (56.5)	41(39.0)	0.6 (0.4-1.2)	0.8 (0.4-1.5)	0.6 (0.2-1.8)	
Perceived weight too heavy						
Yes	55 (29.6)	16 (29.5)	ref	ref	ref	Age, sex, BMI, stress about weight, trying to lose weight
No	128 (68.8)	39 (30.8)	1.1 (0.6-2.1)	1.1 (0.6-2.2)	3.0 (0.8-10.8)	
Trying to lose weight						
No	113 (60.8)	42 (37.2)	ref	ref	ref	Age, sex, stress about weight, depressive symptoms, perceived weight
Yes	70 (37.6)	36 (51.4)	1.8 (1.0-3.3)	1.3 (0.7-2.6)	1.6 (0.7-3.5)	
Depressive symptoms[c]						
0-1.5	57 (30.6)	27 (47.4)	1.0 (0.7-1.4)	0.8 (0.5-1.2)	0.8 (0.5-1.3)	Age, sex, stress weight, binge drinking, trying to lose weight, PDSS, cigarettes, computer, sedentary behaviour
1.6-1.7	65 (35.0)	24 (36.9)				
1.8-5.0	62 (33.3)	30 (48.4)				
PDSS[c]						
0-7	62 (33.3)	24 (38.7)	1.0 (1.0-1.1)	1.0 (1.0-1.1)	1.0 (1.0-1.1)	Age, sex, stress about weight, binge drinking, depressive symptoms
8-13	60 (32.3)	23 (38.3)				

≥14	62 (33.3)	34 (54.8)				

[a]Potential predictor measured in grade 9.
[b]Continuous variables were grouped according to tertile cut-offs for descriptive purposes.
[c]Potential predictor included in the models as a continuous variable. Odds ratio (OR) indicates the increase in the probability of the outcome per 1 unit change in the predictor.
[d]Partially and fully adjusted models were identical.
[e]Not applicable.
[f]Paediatric daytime sleepiness scale (PDSS).
[g]BMI: body mass index.

3.5 DISCUSSION

The purpose of this study was to describe sustained exergaming in a population-based sample of adolescents and to identify factors associated with sustained exergaming. To our knowledge, this is the first investigation of sustained exergaming in a population-based sample. We found that 44% of exergamers reported exergaming two years later. Female sex and having higher introjected PA behaviour regulation were independent correlates of sustained exergaming.

In a recent cross-sectional study of 200 youth who owned exergaming consoles, Simons et al. (2012)[88] found that 11% never exergamed and only 32% exergamed regularly (i.e., >1 hr/wk.). Because of concerns that the novelty of exergaming will dissipate over time, there have been numerous calls to investigate the sustainability of exergaming.[28-30,67,175,179,184] In our study, 44% of exergamers in grade 9, reported exergaming up to twice a week in grade 11, indicating that exergaming may be sustainable among some users. The 44% of sustained exergamers in our study compares to the 41% of girls (but not the 69% of boys) who remained involved in team sports over five years, as observed by Belanger et al. (2009).[211] Although we could not investigate the issue, it is possible that exergaming is an intermittent activity among adolescents. Belanger et al. (2009)[211] reported that between 14% and 53% of adolescents re-engaged in a specific PA after discontinuation. Frequency of exergaming may also be linked to new releases of games and new consoles. Future studies will need more frequent follow-up to assess the stop-start aspect of exergaming over time.

Three-quarters (77%) of participants exergamed at light or moderate intensity. Exergaming at light to moderate intensity may be more enjoyable, practical or achievable among some young persons. Thus, the flexibility of exergaming in terms of level of intensity may contribute to sustainability. More research is needed to investigate whether intensity of exergaming is associated with sustainability.

We previously reported that girls are more likely to exergame than boys,[18] and in this current analysis, girls were also more likely to sustain exergaming. The reasons for sex differences in sustained exergaming may mirror the reasons for sex differences in exergaming. Girls, especially those with body image challenges, may be more comfortable being active at home away from the scrutiny of others, while still enjoying the social interaction provided by exergaming. Boys who play traditional non-active videogames frequently may be attracted by the novelty of exergaming but return to non-active videogames as the novelty wears off.

Although sex differences in exergaming should be further investigated, our results suggest that exergaming may be a viable option to help girls in particular, become and remain active.

A specific focus of this current work was to assess whether PA motivation is associated with sustained exergaming. Self-determination theory (SDT) has been used as a framework to predict intentions to engage in and sustain traditional PA, and investigators have reported that those with higher intrinsic regulation (i.e., motivation) report increased intentions to engage in more PA than those with external PA regulation (e.g.[107,108,110,111]). We found that introjected regulation (i.e., a type of PA motivation indicative of internalization of PA as a behaviour) was a correlate of sustained exergaming. Introjected regulation, a type of PA motivation described in the SDT,[94,101,104] is motivation from an internal pressure which usually drives short-term behaviour change, but does not foster sustainable behaviour change.[94,98] It is generally negatively related or not related to PA levels, although there appears to be sex differences such that girls who report higher introjected regulation also report more PA.[104] The link between behaviour regulation and exergaming has been studied in clinical settings and in specific populations such as overweight youth,[115,116] but few studies investigate this association in population-based samples of youth using the Organismic Integration Theory[93] and it is not fully understood if exercise behaviour regulation differs between those who do and do not sustain exergaming. Sustained exergamers may not be highly motivated intrinsically towards traditional PA and are drawn towards exergaming as a PA alternative. It is also possible that sustained exergamers want to develop skills for fitness and weight change which is fostered through the features of exergaming highlighted in exergames such as fitness games (i.e., body weight, body alignment, placement, feeling, speed, etc. captured by motion and sensor-captures and displayed in real-time on the screen).[117] It is also possible that some of the advertising/marketing of exergames (particularly Wii Fit or Pokémon Go) are designed to play on/play up that guilt, particularly among female users). Future research should focus on better understanding the differences between motivation for PA and motivation for exergaming, which in turn may lead to exergaming interventions that have a greater impact on PA and sedentary behaviour.

We did not identify any predictors of sustained exergaming in this study. Rather than being a planned behaviour, exergaming may be triggered by events in the immediate present such as purchasing a new console or friends coming over, and therefore has few predictors. It is possible that the sample size was too small to detect factors associated with sustained

exergaming longitudinally. Alternatively, because exergaming is relatively new area of research, we may not have investigated relevant predictors.

Limitations of this study include the small sample size, that self-report data are subject to misclassification, that loss to follow-up may have resulted in selection bias, and that restriction of the sample to Francophones may have limited external generalizability. Because we did not collect data more frequently, we could not confirm whether participants exergamed between data collection cycles.

3.6 CONCLUSION

Because exergaming is sustained among girls in particular, it may represent a novel approach to help adolescents remain physically active during a period in the life course notable for sharp declines in PA. Exergaming may be more likely to be sustained if games include components that foster intrinsic PA motivation.

TRANSITION TO STUDY 3

Study 2 investigated the sustainability of exergaming over 3 years in a population-based sample of adolescents and identified factors associated with sustained exergaming. We found that being female and having higher introjected regulation (i.e., a type of PA motivation indicative of internalization of PA as a behaviour) were independent correlates. These results will inform the development of sustainable exergaming interventions.

As described in the introduction, the SDT is a motivation theory frequently used in PA research. Because introjected regulation (i.e., an external type of motivation towards PA) was related to sustained exergaming, we began to question what motivates young people to choose to exergame. There is certainly a strong allure to traditional videogaming which keeps people tied to a screen for hours, which has not necessarily been the case for exergaming. We questioned whether motivation for exergaming related to interest in gaming in general or did the possible health benefits of exergaming play a role.

Our questioning led us to search the literature for a scale to measure motivation or reasons to exergame. We found the Motivation for Exergame Play Inventory, but this scale was not ideal for use in observational studies because it pertained to situational exergaming. Therefore, it became clear that to increase our understanding of reasons to exergaming, a new tool needed to be developed. In addition, in order to inform interventions, we wanted to preliminarily disentangle fitness reasons to exergame (i.e. exergaming to increase PA) and exergaming for pure enjoyment (i.e. exergaming intrinsically). As most clinical studies using exergaming to increase PA were with specific populations (ex. overweight youth), motivations for exergaming in population of exergamers had not yet been explored.

Also, our measures of exergaming behaviour (i.e., frequency, timing, duration) had not yet been tested for validity or reliability. Therefore, Study 3 (which comprises two studies) describes the development and reliability of a new scale (i.e., the Reasons to Exergame scale (RTEX)), which will enhance understanding of the reasons youth choose to exergame. In addition, we tested the reliability of exergaming behaviour measures.

CHAPTER 4

STUDY 3

DEVELOPMENT AND VALIDATION OF THE REASONS TO EXERGAME (RTEX) SCALE.

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ABSTRACT

Objectives. Exergaming is associated with positive health benefits. However, little is known about what motivates the decision to exergame in young people. Our objectives were twofold: to develop, validate and describe the psychometric properties of a new Reasons to Exergame (RTEX) scale, and to examine the test-retest reliability of self-report exergaming behaviour measures. **Methods.** In Study 1, we identified scale items, conducted an exploratory factor analysis of the RTEX scale, and examined how the factors identified relate to frequency and intensity of exergaming in a population-based sample of 265 young adults. In Study 2, we examined the test-retest reliability of the RTEX scale and of self-report measures of past-week exergaming duration and intensity among 147 college students. **Results.** We identified four factors in the RTEX scale: *exergaming for fitness, exergaming for enjoyment, preferring exergaming over other gaming options,* and *choosing exergaming after evaluating competing interests (i.e., preferring exergaming to sports).* The test-retest reliability of the four factors (κ ranged from 0.7 to 0.8) and self-report exergaming duration (κ ranged from 0.4 to 0.9) was adequate. *Exergaming for fitness* and *enjoyment* were positively associated with frequency of exergaming with friends and family, and with exergaming intensity. **Conclusions.** The RTEX scale provides a psychometrically sound instrument to measure reasons for exergaming. There was evidence of test-retest reliability for all four factors that comprise RTEX and evidence of convergent construct validity against exergaming behaviour for two of the four factors. Future studies should attempt to replicate these findings in larger and more diverse samples.

4.1 INTRODUCTION

Because PA levels established in childhood track into adulthood[4] and because not all youth meet recommended PA levels (about 40% of Canadian children and youth aged 5 to 17 years meet the recommended targets for PA in 2016-17)[6,128-130] physically active lifestyles should be promoted early in life. However, both low PA levels and sedentary behaviour are increasing in youth,[193,212] in part due to the popularity of screen activities such as television-viewing and videogame playing (also referred to as gaming). Estimates suggest that 97% of Americans age 12–17[59] and 56% of young adults age 18-25 report past-year gaming using personal computers, laptops, consoles or smartphones.[213] The average time spent gaming among youth has increased, and young adults spend more than 7 hours weekly playing videogames.[214]

There is, however, a type of gaming that may confer physical and mental health benefits and that does not contribute to sedentary behaviour. Through its incorporation of PA into the videogame concept, exergaming (i.e., active videogame-playing) is a contemporary alternative to traditional gaming.[146,147] Exergaming can be defined as a technology-driven physical activity, that uses a screen such as a video game, that requires participants to be physically active in order to play the game. These games require the user to apply full body motion to participate in virtual sports, in group fitness exercise or other interactive physical activities. Exergaming increases EE[60-62,81,215,216] and PA,[30,31,74] helps players manage weight,[71,72,170] improves mental health,[24] and can replace sedentary behaviour.[15,24,31,168] One drawback however, is that both anecdotal and qualitative evidence suggest that, in contrast to more sedentary gaming,[217,218] motivation for exergaming decreases over time, in part because of the challenges of technical difficulties (e.g., consoles malfunctioning, over- or under- sensitivity of controls and inaccurate tracking) and because the novelty of exergaming diminishes over time due to its repetitive nature.[26,31,163] It is unclear empirically whether these declines relate to the gaming nature of exergames (e.g., the lack of compelling narratives), the PA (e.g., sweating and breathing hard while playing) or to competing interests. Similar to both traditional videogames and PA in youth, these factors may differ by sex.[217] For example, PA declines much earlier and more rapidly among females than males[2,126,219] and males initiate video gaming at a younger age than females.[218,220]

Previous investigations of exergaming motivation have used motivation scales developed for other behaviours such as traditional PA.[116] Fitzgerald et al. (2010) used the Self-Motivation Inventory,[115] a 40-item questionnaire which assesses the trait of self-motivation (i.e., the inherent

ability to persevere at a task) as well as the Intrinsic Motivation Inventory, a questionnaire based on the SDT, to assess motivation for exergaming. Sun (2013) used the 15-item Situational Interest Scale–Elementary School[221] to measure situational interest in exergaming among physical education students in elementary school. Neither scale was developed specifically for exergaming. Because exergaming may not be viewed as PA by youth, these scales might not distinguish between motivation for the PA aspects of exergaming and the video gaming aspects.

In the only study to date that examined motivation related specifically to exergaming using a scale developed for exergaming, Staino et al. (2012)[118] used the self-report Motivation for Exergame Play Inventory,[79] a validated 28-item questionnaire that assesses motivation for exergaming among youth with overweight or obesity. However, the Motivation for Exergame Play Inventory measures motivation after an acute bout of exergaming related to the specific game just played, not motivation towards exergaming in general, and is not ideal for examining exergaming motivation in population-based studies or in surveillance. Thus, a critical gap in improving the impact of exergaming interventions is the lack of evidence on factors underpinning the decision to initiate and sustain exergaming. Indeed, increased understanding of factors motivating exergaming (i.e., reasons to exergame) could clarify how youth choose which exergames they play, allowing improvements in exergaming interventions as well as public health messaging about exergaming.

The purpose of this current investigation was to develop and validate the Reasons to Exergame (RTEX) scale. Following item generation, two studies were conducted to test the reliability and validity of the RTEX. In Study 1, we conducted an exploratory factor analysis (EFA) of the new scale. To test construct validity and provide evidence of convergent construct validity, we studied how the factors identified in the EFA relate to the frequency and intensity of exergaming. In Study 2, we assessed the test-retest reliability of both the RTEX scale and self-report measures of exergaming behaviour (i.e., duration and intensity of exergaming in the past week) among college students.

4.2 METHODS

4.2.1 Study 1 - Development and EFA of the RTEX

4.2.1.1 Participants and Procedures

Data for this study were collected in self-report questionnaires completed in 2018-19, in cycle 23 of the Nicotine Dependence in Teens (NDIT) Study[206] when participants were age 30 years on average (n=630). NDIT is an ongoing investigation of grade 7 students recruited in 10 Montreal-area high schools in 1999-2000.[19] Of 2325 eligible students, 56% participated at baseline. The low response related to the need for blood samples for genotyping and to a labour dispute in Quebec that resulted in numerous teachers refusing to collect consent forms. No data were collected from nonrespondents.[19] Self-report questionnaires were administered at school every 3 months during the 10-month school year in grades 7-11, for a total of 20 cycles during the 5 years of high school. Post-high school data were collected in self-report questionnaires in 2007- 08 (cycle 21), 2011-12 (cycle 22) and 2018-19 (cycle 23), when participants were aged 20, 24 and 30 years on average, respectively. The current study uses data from cycle 23. The NDIT Study was approved by the Institutional Review Board of the Ethics Research Committee of the Centre de Recherche du Centre Hospitalier de l'Université de Montréal. This current study received approval from the Concordia University Ethics and Protection Review Board. Participants provided informed consent.

4.2.1.2 Measures

Reasons for Exergaming Scale (RTEX)

RTEX items were developed by the authors in consultation with PA and exergaming experts based on constructs relevant to exergaming including general interest in videogames, social gaming preferences, degree of enjoyment of exergaming, reasons to be physically active (i.e., to lose weight, increase strength) and to compare exergaming with other active pastimes such as sports. Items were inspired by the Gaming Motivation Scale,[222] the Intrinsic Motivations to Gameplay scale[223] and the Exercise Motivations Inventory–2.[224] The scale was pilot-tested among experts as well as among young adults age 30 years on average during the development of NDIT cycle 23, for clarity of wording, item choice and clarity of the response format. A five-point Likert-type response format was selected. Participants were asked to indicate how true each

statement was regarding their reasons to exergame using the following response choices: completely false, slightly false, neither true nor false, slightly true and completely true.

Exergaming frequency and intensity

Items measuring the frequency and intensity of exergaming were modelled on the short-form self-administered usual week International Physical Activity Questionnaire (IPAQ), which is used in cross-national monitoring of PA in youth and adults and demonstrates reliability and validity against the accelerometer.[207] Specifically, exergaming was measured by asking participants: "Do you exergame using consoles such as Nintendo Wii, XBOX ONE Kinect, Sony Play Station Move, Sony Eye Toy: Kinetic, or using your cellphone and/or a mobile app? (ex. ZOMBIES, RUN!, Nike+ Running App, Fit Freeway, Pokémon Go)" (yes/ no). Those who responded "yes" were asked how many days per week they played active videogames (exergamed) (1–7 days); how many minutes (on average) they played each time (open-ended); and perceived effort of play (light, moderate, vigorous). Finally, we investigated the frequency participants exergamed alone, with friends, or with family by asking: "How often do you exergame with… (friends, family, alone)?" Response options included *never, rarely, sometimes, often, very often*. These measures were used in both Study 1 and 2.

4.2.1.3 Statistical Analysis

Since the 26 items in the RTEX scale were expected to inter-correlate, they were subjected to an EFA using maximum likelihood and oblique promax rotation (i.e., direct oblimin) for factor derivation. Criteria[225] used to establish the number of factors to retain included: (i) the Cattell scree plot; (ii) that >10% of variance was accounted for by each factor; (iii) that pattern coefficients were > 0.40 on a given factor; (iv) interpretability of the factors; and (v) that internal reliability (i.e., Cronbach's α) of the factors was > 0.7.[226] The Kaiser–Meyer– Olkin test was used to measure sampling adequacy for conducting a factor analysis. Factor items were also determined using Eigenvalues > 1. Pattern coefficients above 0.40 represent fair to excellent loading criteria and were deemed acceptable (e.g.,[227]). Factor scores were calculated by summing the individual items within a factor and averaging the score by the number of items with responses to create one score per factor.

Convergent validity

The association between each factor retained and exergaming frequency (in minutes per week) and intensity (i.e., light, moderate, intense) were examined in separate multivariable linear regression models. We also investigated the association between each factor and the frequency of exergaming alone, with friends and with family, in separate multivariable linear regression models. All five regression models controlled for age, sex, mother's education (i.e., attended university (yes/no)) and the other three factors. Sex differences in the factors and individual items were examined using independent t-tests.

4.2.1.4 Results

Table 8 shows selected characteristics of NDIT participants (n=265), who were part of the analytic sample (responded yes to ever exergaming). Twenty-six items were retained for the initial EFA. The Kaiser–Meyer–Olkin measure of sampling adequacy (0.90) and the Bartlett's test of sphericity (4494.7, df = 325, $p<0.0001$) indicated that the correlation matrix was appropriate for this analysis. Six factors with eigenvalues >1.0[228] were extracted from the matrix, explaining 71.2% of the variance. Based on the analysis of the loadings of the rotated factors (i.e., the pattern matrix), three items were dropped from the item pool because they failed to load > 0.40 on any of the four factors (Appendix G). We repeated the factor analysis with the remaining 23 items and examined the factor loadings of the new promax-rotated factor solution. Five factors emerged, which explained 70.0% of the total variance. Inspection of the pattern matrix showed that all items but one, loaded > 0.40 on one of the five factors (Appendix G), and none of the items had high cross-loading on other factors. Therefore, after removing the one item, the process was repeated a final time, and a 4-factor solution explaining 66% of the variance was retained (n=22 items).

Table 8. Selected characteristics of participants in Study 1 (n=265), NDIT 2018-12

Characteristic	
Age, y, mean (SD)	30.2 (0.7)
Male, %	46.8
French-speaking, %	36.0
Mother university-educated, %	40.2
Canadian-born, %	96.4
Minutes exergaming per week (total exergaming sample), mean (SD)	30.1 (90.0)
Minutes exergaming/week (excluding those reporting 0 minutes), mean (SD)	147.0 (150.7)
Intensity of exergaming, %	
Light	64.8
Moderate	33.8
Intense	1.4

Frequency exergaming alone, mean (SD)	2.1 (1.2)
Frequency exergaming with friends, mean (SD)	2.1 (1.0)
Frequency exergaming with family, mean (SD)	1.8 (0.9)

The 4-factor solution included a fitness factor (9 items), a value-added factor (8 items), a gaming preference factor (3 items) and an attractive alternative (preferring exergaming to sports) factor (2 items) (Table 9). The mean (standard deviation) for factors 1 to 4 were 1.7 (1.0), 3.3 (1.0), 1.9 (1.0), and 1.8 (1.1), respectively. The correlation matrix of the factor solutions showed that the four factors were moderately correlated, ranging from r=0.20 to r=0.40. Items were summed and averaged to compute factor scores (Table 10). Cronbach's alpha for the factors ranged from 0.80 to 0.90 (Table 10), indicating adequate internal consistency. Sex differences were observed in the fitness and gaming preference factors - females scored higher on both factors, indicating that these factors were more important or true for them as reasons to exergame (Table 9).

Table 9. Mean (standard deviation SD)) scores by sex and factor loadings of items retained in each RTEX factor, Study 1, n=265, NDIT 2018-19

Factor	Items within factors	Score Mean (SD)			Factor loading
		Total	Males	Females	
Factor 1-Fitness*	I exergame to maintain my weight	1.7 (1.1)	**1.9 (1.2)**	**1.5 (1.0)**	0.87
	I exergame to maintain my level of fitness	1.8 (1.2)	**2.0 (1.3)**	**1.6 (1.1)**	0.86
	I exergame to be more active	2.2 (1.3)	**2.4 (1.4)**	**2.0 (1.2)**	0.70
	I exergame to lose weight	1.8 (1.2)	**2.0 (1.3)**	**1.5 (1.0)**	0.83
	I exergame to gain strength	1.6 (1.1)	**1.8 (1.2)**	**1.5 (1.0)**	0.89
	I exergame to "bulk up"	1.4 (1.0)	1.3 (0.7)	1.4 (0.8)	0.77
	I exergame to gain flexibility	1.9 (1.1)	1.8 (1.2)	1.5 (1.0)	0.90
	I exergame to gain balance	1.7 (1.1)	1.8 (1.2)	1.6 (1.0)	0.88
Factor 2-Enjoyment and value*	I like to play exergames	3.2 (1.4)	3.2 (1.4)	3.2 (1.3)	0.73
	I like to play exergames with friends	3.3 (1.4)	3.4(1.4)	3.2(1.4)	0.81
	I like to play exergames with my family	2.8 (1.5)	**2.6(1.4)**	**3.0(1.5)**	0.60
	Exergames are boring to play (reverse coded)	3.5 (1.3)	3.5(1.3)	3.6(1.3)	0.50
	I exergame to be social	2.5 (1.5)	2.5(1.4)	2.5(1.5)	0.60
	Exergames are exciting to play	2.9 (1.3)	**2.8 (1.3)**	**3.1 (1.2)**	0.67
	I exergame just for fun	3.5 (1.4)	3.6 (1.4)	3.4 (1.5)	0.72
	I prefer exergames to watching TV***	2.0 (1.1)	**1.8 (1.1)**	**2.1 (1.1)**	0.41
	I prefer exergames to being on social media (Facebook, Instagram, Snapchat)	2.3 (1.4)	**2.0 (1.2)**	**2.8 (1.4)**	0.44
Factor 3- Gaming preference*	I prefer exergames to more traditional videogames ***	2.4 (1.3)	**1.8 (1.1)**	**2.8 (1.3)**	0.60
	Exergaming is the only type of videogame I like	1.5 (1.1)	**1.3 (0.8)**	**1.8 (1.2)**	0.81
	Other types of videogames bore me	1.6 (1.1)	**1.4 (0.9)**	**1.9 (1.3)**	0.81
Factor 4- Alternative attractions*	I prefer to play exergames more than outdoor sports	1.8 (1.1)	1.8 (1.2)	1.8 (1.1)	-0.90
	I prefer to play exergames more than indoor sports	1.9 (1.2)	2.0 (1.2)	1.8 (1.1)	-0.84

*Continuous variables

**Bolded items are statistically significantly different by sex ($p \leq 0.05$)

***Items were not tested in test-retest analysis

Table 10. Mean (standard deviation (SD)) score and internal reliability coefficient (Cronbach's alpha) of RTEX factors by sex (Study 1, 2018-19) and intraclass correlation coefficient (ICC) and confidence intervals (CI) for test-retest reliability of RTEX factors (Study 2, 2018)

RTEX factors	Mean (SD) Study 1 n=265	Range	Cronbach's Alpha	ICC (CI) Study 2 n=147
Factor 1: Fitness			0.95	0.8(0.6,0.8)
Total	1.7 (1.0)	1.0-4.5		
Male	**1.6 (0.9)**			
Female	**1.9 (1.0)**			
Factor 2: Enjoyment value			0.85	0.7(0.4,0.6)
Total	2.9 (0.9)	1.0-4.8		
Male	3.0 (0.9)			
Female	2.9 (0.9)			
Factor 3: Gaming preference			0.80	0.8(0.5,0.7)
Total	1.9 (1.0)	1.0-5.0		
Male	**1.5 (0.7)**			
Female	**2.2 (1.1)**			
Factor 4: Alternative attractions			0.90	0.7(0.6,0.8)
Total	1.8 (1.1)	1.0-5.0		
Male	1.8 (1.0)			
Female	1.8 (1.1)			

*Bolded items are statistically significantly different by sex ($p \leq 0.05$)

Convergent construct validity

Correlations between the motivation factors and exergaming behaviour are presented in Table 11. Multiple linear regression analysis indicated that Factor 1 (fitness) was related to exergaming intensity (β = 0.2, 95% confidence interval [CI] 0.03, 0.4), frequency exergaming alone (0.3 (0.1,0.5)), and frequency exergaming with friends (-0.2 (-0.3, -0.05)). Factor 2 (enjoyment value) was related to frequency of exergaming alone (0.3 (0.1, 0.5)), frequency of exergaming with friends (0.7 (0.6, 0.8)) and frequency exergaming with family (0.5 (0.3, 0.6)). Factors 3 and 4 were not related to exergaming behaviour or frequency exergaming with friends, family or alone.

Table 11 - Bivariate correlations among variables used in the regression models, Study 1, NDIT 2018-19

	Factor 1 Fitness	Factor 2 Enjoyment and value	Factor 3-Gaming preference	Factor 4-Alternative attractions*	Min. exergaming per week	Intensity exergaming	Frequency exergaming: Alone	With friends	With family
Factor 1-Fitness	1	0.273**	0.312**	0.432**	0.042	0.325**	0.327**	0.067	0.162**
Factor 2-Enjoyment and value		1	0.227**	0.439**	0.185**	-0.054	0.302**	0.625**	0.462**

Factor 3- Gaming preference			1	.213**	0.062	0.074	0.135*	0.165**	0.230**
Factor 4- Alternative attractions*				1	0.128*	0.034	0.285**	0.295**	0.259**
Minutes exergaming per week					1	-0.067	0.432**	0.145*	0.065
Intensity exergame						1	0.301*	0.021	0.046
Frequency exergame alone							1	0.180**	0.118
Frequency exergame friends								1	0.527**
Frequency exergame family									1

**Correlation significant at the 0.01 level (2-tailed).
*Correlation significant at the 0.05 level (2-tailed).

Table 12. Percent or mean of responses to the items measuring exergaming behaviour by sex, Study 1, NDIT 2018-19

Exergaming Behaviour	n	Exergaming behaviour or RTEX item	Study 1		
			Total	Males	Females
Ever exergamed	627*	Have you ever exergamed using a console, cell phone and/or mobile app? % yes	44.4	46.6	42.5
How often – console*	257	How often do you exergame using consoles such as Nintendo Wii, XBOX ONE Kinect, Sony Play Station Move, Sony Eye Toy: Kinetic? * (never, <1/month, 1-2/month, 1-3/week, 4-6/week, everyday) recoded **≥1/week, % yes**	17.1	**25.2**	**14.1**
How often – mobile*	268	How often do you exergame using your cellphone and/or a mobile app? (ex. ZOMBIES, RUN!, Nike+ Running App, Fit Freeway, Pokémon Go) * ((never, <1/month, 1-2/month, 1-3/week, 4-6/week, everyday) **recoded ≥1/week. % yes**	34.3	37.7	31.2
Days per week	62	In the past month, on how many days per week did you exergame using a videogame console such as the Nintendo Wii, XBOX 360 Kinect, Sony Play Station Move, Sony Eye Toy: Kinetic? Write 0 if none (open-ended), mean (SD)	0.7 (1.7)	0.9 (2.0)	0.5 (1.5)
Minutes per bout	62	On average how many minutes did you spend each time you did this? Write 0 if none* (open-ended), mean (SD)	44.9 (35.0)	50.2 (39.5)	37.5 (28.6)
Intensity	72	What was your level of effort when you did the activity? %			
		Light	63.0	70.0	56.3
		Moderate	35.7	27.5	43.8
		Intense	1.4	2.5	0.0

* This is the n in NDIT survey cycle 23, where 44% had ever exergamed and n=265 were included in the analytic sample (i.e. who responded to RTEX items)
**Bolded items are statistically significantly different by sex ($p \leq 0.05$)

4.2.2 Study 2 - Test-retest reliability of RTEX

Students (54.6% female; M(SD) age= 19.5(0.5)) recruited from an Exercise Science Department at a large urban university (n = 147) completed the RTEX on two occasions (Time 1 and 2) 7-9 days apart in winter 2017. The study received approval from the ethics and protection review boards of Concordia University and students provided assent during questionnaire administration. Students received class credit for completing the study.

4.2.2.1 Statistical analysis

Intraclass correlations (ICCs) were used to examine test-retest reliability between responses over time for continuous variables including exergaming intensity and days per week

exergaming [10]. Two-way random ICCs were computed and the average ICC was reported.[229] Adequate test-retest reliability was defined as ICC $\geq$ 0.75 [11]. The weighted Kappa statistic (κ) was used to describe the test-retest reliability of categorical variables (ever exergamed (yes/no)), and the strength of agreement between responses was defined as poor to fair (κ=0.0-0.4), moderate (κ=0.41-0.6), substantial (κ=0.61-0.8) and almost perfect (κ=0.81-1.0). Statistical significance was set at 0.05.

4.2.2.2 Results

ICCs and Kappa coefficients for exergaming duration and intensity ranged from 0.4 (for intensity) to 0.9 (for days per week exergaming). The Kappa for ever exergamed was 0.7. Test-retest reliability of RTEX Factors 1 to 4 ranged between 0.7 and 0.8 (Table 12).

4.3 DISCUSSION

This research describes the development and validation of a new scale that measures general motivation and reasons to exergame. RTEX incorporates four factors indicative of motivation to exergame, including exergaming for fitness, exergaming for its enjoyment value, preferring exergaming over other gaming choices and evaluation of competing interests (i.e., preferring exergaming to sports). RTEX factors were internally consistent and had adequate test-retest reliability. Because a primary goal of gaming is to provide motivational affordances (i.e., how the game creation environment invites and maintains motivation),[230] identification of motivational attributes is key to designing games and gamified systems that are sustainable.[23,30,163]

Because enjoyment is central to maintaining or increasing motivation for PA generally and exergaming specifically, exergame developers will need to incorporate elements to increase enjoyment or that help increase intrinsic motivation among those who exergame primarily for external fitness reasons.[231,232] For example, games that provide external motivation through ongoing feedback on physical form, effort and progress in the game, may need to include components that increase enjoyment and autonomy (e.g., providing more choices within the game, goal setting). Increasing or focusing on intrinsic motivation to encourage sustainable use among those who exergame for fitness may help increase exergaming sustainability,[233] and

assessing an individual's motivation for exergaming will be key when prescribing exergaming in an intervention or by health practitioners.[234]

Two of the four factors identified demonstrated convergent construct validity against exergaming frequency and intensity, which are important outcomes in evaluating exergaming as a method to increase PA and reduce sedentary behaviour.[23] Specifically, participants who exergamed for fitness, fun or enjoyment reported a higher frequency of exergaming socially. Also, the fitness factor was associated with exergaming intensity, frequency, exergaming alone and exergaming with friends. Individuals who score higher on the fitness factor may exergame purposely to lose or maintain weight or to bulk up, which is extrinsic motivation according to the SDT,[231] a framework that predicts intentions to engage in and sustain traditional PA. Investigators have reported that intrinsic regulation (i.e., motivation) relates to intentions to engage in more PA than external PA regulation.[232]

Our results align with SDT,[235] where enjoyment and fun (internal motivations) (Factor 2) were positively related to frequency of exergaming with friends, family and alone. The items in Factor 2 encompass intrinsic reasons for exergaming (i.e., fun, enjoyment, excitement, preferences, autonomy). Therefore, games, gamified systems and exergaming interventions should be designed to permit experiences such as autonomy, that are intrinsically motivating.[235] Our results align with those of a study on Pokémon, in which the authors reported that the social aspect of the game was one of the strongest predictors of sustained gameplay.[22]

The factors measuring gaming preferences and alternative attractions were not related to exergaming duration or intensity (i.e., individuals who prefer exergaming over traditional videogames or sports do not exergame at different intensities or frequencies than individuals who do not prefer exergaming). The items in these two factors tap overall motivation and reasons to choose exergaming over traditional videogames or sports, which may not be associated with exergaming behaviour, at least as we have measured it. In other words, preferences do not necessarily translate into exergaming behaviour.

Sex differences were apparent in the fitness and gaming preference factors. Although preferences were not associated with exergaming behaviours, the sex difference in preferences may explain some of our results. Specifically, compared to males, females preferred exergames over traditional videogames and scored higher on the fitness factor. Consistent with previous work,[18,34,117] females may exergame to incorporate PA into their lives, whereas males play for

fun and enjoy gaming (whether exergaming or traditional videogames) as a pastime in general.[217] If replicated, exergaming interventions may need to incorporate different 'prescriptions' for males and females.

Our measures of exergaming duration and intensity, which were modelled after the I-PAQ,[236] have been used in previous studies,[18,34,117] but their test-retest reliability is unknown. In this study retest reliability was adequate. Given its popularity, monitoring trends in exergaming behaviour should be incorporated into PA surveillance and the items tested herein could be considered for use in surveillance systems, except for the item on exergaming intensity which needs further work.

We measured motivation to exergame using the RTEX, exergaming frequency and gaming intensity, all of which may underpin exergame play that leads to sustainable healthy PA. The RTEX scale can provide a reliable and valid assessment of reasons to exergame and has promise in terms of increasing the evidence base that informs the design of sustainable exergames and exergaming interventions. Our results indicate that the RTEX and exergaming behaviour measures have solid psychometric properties and therefore have promise in terms of evaluating exergaming at a population-based level.

Limitations of this study include that self-report data are subject to misclassification. The external generalizability of the findings was not addressed empirically so that future research should examine the RTEX in more diverse populations.

4.4 CONCLUSION

In this study, we introduce the RTEX, an instrument that assesses reasons to exergame. Future research should examine the psychometric properties and the reliability and validity of the RTEX in diverse samples to ascertain whether the scale is useful in the broader population. Our data suggest that there are sex differences in RTEX, a tenet that requires further exploration. Identifying factors that contribute to the sustainability of exergaming is another important area of research. Finally, to enhance population-based surveillance, testing the validity of exergaming behaviour self-reports against objective measures (e.g., using the exergame itself as a measure or accelerometer usage) is warranted.

CHAPTER 5
GENERAL DISCUSSION

5.1 SUMMARY OF RESEARCH FINDINGS

Guided by the SDT, the aim of this dissertation was to increase understanding of the role of motivation in exergaming behaviour. We first examined the role of motivation in exergaming in a review of the literature. Specifically, the objective of Study 1 was to summarize evidence from systematic reviews and meta-analyses on the associations between exergaming and: (i) PA, sedentary behaviour and EE; and (ii) body composition, BMI and weight outcomes among persons less than 30 years of age; and (iii) to summarize the recommendations in the articles retained. The results of Study 1 demonstrated that exergaming is likely more health-promoting than traditional videogames because of higher EE, decreases in time spent in sedentary behaviour and possibly improved physical fitness, body composition and cognitive health. However, we identified important gaps in the exergaming literature. Research examining whether exergaming is a sustainable behaviour that results in positive changes in body composition or health effects over time is warranted. In addition, more longitudinal studies are needed to assess whether exergaming reduces sedentary behaviour time. Finally, we identified that few studies use behavioural change theories to guide their interventions or to design exergames. We recommended that exergaming interventions be designed using behaviour change theory such as the SDT.

The objectives of Study 2 in this dissertation were, in a real-life setting, to: (i) describe the sustainability of exergaming over 2-3 years in a population-based sample of adolescents; and (ii) to identify factors associated with sustained exergaming. In our sample, 44% of grade 9 exergamers reported exergaming two years later. Being female and having higher introjected regulation (i.e., an external type of PA motivation) were independent correlates of sustained exergaming. Exergaming may represent a novel approach to help adolescents (females in particular) remain physically active during a period in the life course notable for sharp declines in PA. Although sustainability was observed among those with introjected regulation (i.e., an external regulation), this type of motivation was measured in the context of PA in general and was not specific to exergaming. Exergaming may be more likely to be sustained if games include components that foster intrinsic PA motivation such as providing more choices in the games

offered (i.e., who the game is played with, if the setting is collaborative or competitive, how intensely the game is played). In addition, having a coach and/or other social support while learning a new game may also foster intrinsic motivation in exergaming interventions. We concluded that exergaming may be a practical approach to help adolescents maintain PA during adolescence and that exergaming interventions may need to consider sex and PA motivation in their design and implementation.

Results from Study 1 demonstrated that research on motivation related to exergaming is sparse and is rarely guided by theory. The aim of the third study in this dissertation was to develop and validate a scale designed to measure motivations for exergaming (i.e., the Reasons to Exergame scale, or RTEX). We used EFA of the new scale to identify factors and then we tested their associations with exergaming behaviour. To provide evidence of convergent construct validity, we studied how the factors retained relate to the timing and intensity of exergaming (two important facets of PA). We then reported the test retest reliability of the RTEX factors and our measures of exergaming behaviour. This is a novel contribution because there is currently no gold standard measure of exergaming behaviour in population-based studies. We concluded that the RTEX scale provides a reliable and valid assessment of reasons to exergame and has promise in terms of increasing the evidence base that informs the design of sustainable exergames and exergaming interventions. Our results indicated that the RTEX and exergaming behaviour measures have fair to solid psychometric properties and therefore have promise in terms of evaluating exergaming at a population-based level.

5.2 COMMONALITIES ACROSS STUDIES

The popularity of exergaming appears to be increasing. We compared the prevalence of exergaming in Study 2 and 3. Study 2 included adolescents and the data were collected in 2012 - 25% of youth reported exergaming in the past year. In Study 3, 55% of young adults reported lifetime exergaming and 20% had exergamed in the past year (i.e., 2018). Exergaming may be more popular in children and adolescents and yet one in five young adults had exergamed in the past year, suggestive that this activity is highly prevalent even among older youth and young adults. As games for health and “serious games” are the subjects of much research, it is important to monitor trends in exergaming under the umbrella of games for health. The current

research validated such a tool, which can be used to monitor exergaming behaviour in population-based samples.

An interesting finding across Study 2 and 3 is the emergence of sex differences - first in the sustainability of exergaming, and second in the motivating factors identified by the RTEX. Specifically, we found that adolescent girls were more likely to sustain exergaming over time and that young adult female exergamers were more likely to report being motivated to exergame for fitness reasons, and less likely to report preferring traditional videogames over exergaming. There were no sex differences in the RTEX for the enjoyment and value factors, or in evaluation of alternative pastimes (i.e., sports).

In general, boys are more physically active than girls and tend to engage in higher-intensity PA.[126] Sex is also a strong predictor of videogame play over and above socioeconomic status and ethnicity,[237] and boys play videogames more often and for greater durations than girls. Sex differences in exergaming have been investigated in previous research, and the results are mixed. Lam et al. (2011)[92] reported that when given a choice, boys and girls choose to exergame for similar durations.[92] Sun et al. (2013)[199] found that during a physical educations intervention, boys and girls were equally active in exergaming lessons, but boys perceived their gaming experiences as more enjoyable, although this did not translate into a higher intensity of exergaming.[65] The authors suggested that the games tested might be more appealing to boys providing greater feelings of reward and leading to higher levels of enjoyment.[65] However, Soltani et al. (2016)[238] found that young adult exergamers simulating swimming, played the game with the same intensity regardless of sex. These studies evaluated interventions or were laboratory-based studies under controlled conditions so that the results may not be generalizable to other populations.

Our research is observational and aligns with previous observational studies in which sex differences were reported. For example, Dutch adolescents not in the enriched curriculum for education were more likely to exergame >1 hour per week than those in enriched education programs, and among those who play videogames and exergames, boys and older adolescents were less likely to exergame[88] than girls. However, Simons et al. (2014)[35] found no significant differences between regular and non-regular exergamers by sex, education level of adolescents or parents, ethnicity or sedentary behaviour.[35] In addition, Barr-Anderson et al. (2018)[89] found that among 2700 youth age 14, male and female exergamers were younger and more likely to be

black and that exergamers did not report significantly more PA than non-exergamers with one exception. Female exergamers engaged in more vigorous PA.[89] Similarly, MacIntosh et al. (2017)[239] examined the effect of acute exergaming on the physiological and psychosocial responses of young adults, as well as on the modulatory effect of a single- or dual-player game play situation. These researchers reported that females had more positive psychosocial responses to exergaming than males, and that order of game play (i.e., whether they played a dual or a single bout of exergaming first) did not differ in terms of motivational or psychological outcomes.[239] Finally, Peng et al. (2012)[102] described how autonomy and competence (i.e., both tenants of the SDT) were mediators of the relationships between game features and motivation and engagement outcomes in a bout of exergaming.[102] Overall, findings in the literature and the current study's suggest that sex is important in the enjoyment of, and reasons to exergame, which impacts the timing and intensity of exergaming play. In addition, several studies suggest that heightened feelings of presence are often associated with enjoyable game-playing experiences,[240-245] but may differ depending on the game, avatar (i.e., the user's character simulation) and music. Song et al. (2011)[245] reported significant interaction effects suggestive that seeing the image of one's self on screen in the exergaming experience, works positively for individuals with low body image dissatisfaction, but negatively for those with high body image dissatisfaction. Whether the goal of an intervention is to reduce sedentary behaviour or increase PA, these types of sex differences should be considered. Our findings suggest that interventions should be tailored to sex in game choice, game intensity (i.e., challenge level), level of competitiveness, time of play, gaming preferences and goals. One of the strengths of exergaming is that it permits individualization, which is currently underused in exergaming interventions. An exergaming session may be tailored to the needs of the individual (i.e., adapted to fitness level, preferences according to sex).

In addition to the importance of sex in exergaming, a novel contribution to the literature is that motivation, a tenant of SDT, is important to sustained exergaming behaviour. Although preliminary, our results suggest that fitness reasons as identified by the RTEX factor (e.g., losing weight) in Study 3 are important reasons to exergame among young adults, translating to more frequent playing. This finding is aligned with findings from Study 2 (on sustained exergaming) such that individuals with introjected regulation towards PA are more likely to sustain exergaming. Introjected regulation as measured in Study 2, does not evaluate motivation towards

exergaming directly, but towards PA in general. Exercising to lose weight and improve appearance (i.e., external reasons to exercise (introjected regulation)) is a common goal for PA in western culture, particularly among women who tend to endorse these reasons for PA more strongly than men.[246,247] Endorsement of weight loss and increasing muscle tone as reasons to exercise is consistently associated with more negative body image.[246,247] In contrast, citing health reasons for exercising are positively associated with body image.[248] As external PA goals may be improved by exergaming, and this may be why this association between introjected regulation and exergaming behaviour is observed.

Our results suggest that interventions should focus on increasing the internalization of exergaming by using SDT tenants. For example, competence has been associated with intrinsic motivation[94,96,97,104] and many exergames allow users to build up confidence to play at higher levels slowly. Adjustment during exergaming (i.e., by an algorithm combined with immediate feedback to the individual) ensures that training is usually at the appropriate level.[57] Future research should evaluate the relationship between PA motivation, reasons to exergame and exergaming behaviour. In addition, public health messages on exergaming should promote intrinsic motivation such as enjoyment and fun, rather than emphasizing fitness reasons exclusively.

5.3 LIMITATIONS

Limitations of Study 1 include that research to date focuses primarily on commercially available exergames even though other types of exergames (e.g., outdoor mobile\augmented reality games; exergaming gym equipment) are now available. We retained only English and French language reviews, and we excluded qualitative studies. The outcomes of interest in our review included PA, body composition and health. However, several reviews did not focus on a single outcome and it was difficult to categorize reviews that focussed on several outcomes. A meta-analysis was not feasible due to variability across studies in design, outcomes investigated, sampling and measurement. Finally, narrative reviews are limited by the subjectivity of the analysis.

Limitations of Study 2 and 3 include that the small sample sizes of exergamers limited power to detect associations, that self-report data are subject to misclassification, that loss to follow-up may have resulted in selection bias of the estimates, and that restriction of the sample

to Francophones (Study 2) may have limited external generalizability. Although the BREQ-2 is widely used in PA motivation studies, there are limitations to the subscales measuring the motives including acceptable to good Cronbach's alpha (as opposed to excellent) measurements per subscale. In addition, the data in Study 2 were collected in 2012. With the ongoing evolution of exergaming consoles and equipment, sustained exergaming should be assessed with more recent data. It was not possible to assess whether participants exergamed between data collection cycles (Study 2), and more frequent follow-ups are warranted. Studies 2 and 3 measured exergaming using self-report questionnaires, which could have resulted in misclassification of the amount of time spent exergaming. It is warranted for future research to objectively measure exergaming behaviour using the feedback from the consoles or accelerometers. Future studies will need more frequent follow-up to assess the stop-start nature of exergaming over time. Our findings are limited to adolescents and young adults, although exergaming may benefit all ages.

Other general limitations include that although very promising, the current research does not focus on motor skills, cognitive performance or mental health improvements related to the use of exergames. In addition, the transferability of exergaming to nonvirtual reality settings was not examined, although this is an important new direction of exergaming research. Finally, although mobile exergaming has increased in popularity, the research in this dissertation did not distinguish between mobile and console gaming specifically nor measure the time of day youth exergamed at, which may be related to health outcomes such as sleep.

5.4 CONCLUSIONS

It is difficult to ignore the popularity of exergaming. The Xbox 360's Kinect unit (i.e., a motion sensing device used to capture bodily movement and promote PA) sold approximately 25 million units in 2013[249] and Pokémon Go, released on July 6, 2016 by Nintendo, had 25 million active players daily one month after the official release.[250] The key to optimizing exergaming for PA at its fullest potential is to understand how to capitalize on the alluring components of this type of gaming and how to render the activity sustainable. Based on the findings in this dissertation we conclude that, because of exergaming, increased screen time does not have to be synonymous with reduced PA and increased sedentary behaviour. Exergaming should not be viewed as a replacement for traditional exercise and sports, but as an option, an alternative or an add-on to usual PA in the lives of youth possible in all age groups. Exergaming may provide a

useful adjunct to traditional methods of PA and an interesting approach for interventions that aim to increase PA.

Despite the potentially positive aspects of exergaming, improvements can be made as discussed in Study 1. Barriers to exergaming (i.e., technological failure, cost of console equipment, limited one-to-one translation of exergame movements into the games, expensive accessories, injuries or accidents and solo play - see Appendix D for more cited exergaming barriers) must be addressed to encourage interest and sustainability.[51] Overall however, exergame technology enables individuals or groups to play and interact during game play, in a physically active manner.[251,252] Many games and mobile APPs promote healthy dietary and PA behaviours[252] and in addition, they are helpful in educating youth about physical fitness.

5.5 RECOMMENDATIONS

In terms of future research, we recommend that:

(i) reviews of the literature should use standard review criteria to assess the quality of individual studies

(ii) research on exergaming should include a section on recommendations for research and for the design and implementation of exergaming interventions

(iii) future research should examine the sustainability of exergaming using more frequent follow-up over a longer time period

(iv) more research and in particular, longitudinal studies are needed to assess whether exergaming reduces sedentary time and improves health

(v) more research is needed to determine how to maximize the health benefits of exergaming

(vi) the RTEX should be tested in larger and more diverse samples, including further testing on the reason to exergame and exergaming behaviour (i.e. how motivations translate into behaviour)

In terms of exergaming intervention design and implementation, we recommend that:

(vii) exergaming interventions should be designed using behaviour change theory with the objective to increase PA and to maximize sustainability

(viii) future research should consider recommendations from previous research to improve exergaming interventions

(ix) interventions need to take into account the possible sex differences and interest in exergaming

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266. Jacobs K, Zhu L, Dawes M, et al. Wii health: a preliminary study of the health and wellness benefits of Wii Fit on university students. *The British Journal of Occupational Therapy.* 2011;74(6):262-268. doi:10.4276/030802211X13074383957823.

APPENDICES

APPENDIX A

Motivational and De-Motivational Factors Underpinning Physical Activity in Young People

Motivational Factors[192,253,254]

- Enjoyment.
- Self-efficacy
- Behavioural regulation
- Supportive familial environment and parental role modelling.
- Direct involvement with other enthusiastic adults who act as role models (teachers, coaches, etc.).
- Indirect role modelling (professional athlete).
- Peer involvement.
- Easy accessibility to facilities and equipment.
- Feelings of safety and security.
- Feelings of competence (self-efficacy) and improvement.
- Feelings of being in good physical condition (e.g. not overweight).
- Feeling that the activity chosen is a personal choice (no coercion).
- Experimenting with a variety of activities and movements.
- Good weather.

De-Motivational Factors

- Lack of enjoyment.
- Unsupportive familial environment with no parental modelling.
- Lack of other adult role models.
- Unsupportive social environnement (unsupportive peers, teachers, etc.).
- Access to facilities or equipment is difficult.
- Perception that personal safety is at risk or frequent injuries.
- Perception that skills are unattainable (too difficult).
- Feelings of incompetence (lack of self-efficacy) and lack of improvement
- Feelings of embarrassment (e.g. overweight children).
- Lack of choice or feeling pressure to play or compete.
- Activity is “forced” (e.g. used as punishment).
- Continually doing the same activity repeatedly (repetition).
- Placing more importance on winning than playing.
- Bad weather.

APPENDIX B

Variables Related to Players' Gaming Experiences

The gaming experience may differ according to which console is used. Thin et al.(2012)[255] compared dance-based exergamers on three consoles that used different tracking technologies. Although no differences were found in measures of exertion across consoles, there were significant differences in the self-report level of difficulty and enjoyment ratings. In-game experiences also influence enjoyment and the likelihood of continued use of exergamers. Limperos et al.(2016)[243] found that college students who performed better while playing "The Biggest Loser" reported greater enjoyment than those who did not perform well. Enjoyment and presence were also found to mediate the relationship between player performance and future intentions to play. These findings are similar to research on game experience in traditional videogames where player performance and game difficulty have been found to affect enjoyment [256,257]. Using the Self-Determination Theory as guidance, studies repeatedly demonstrate that experiences resulting from active gameplay can be intrinsically fulfilling and enjoyable[103,258,259]

Physical setting (school, lab, community, home) - Using accelerometers and self-report questionnaires Gao et al., 2013[64] found that playing Dance Dance revolution did not increase Moderate-to-Vigorous PA time over regular aerobic activities in a school based intervention, although the children did report higher self-efficacy and higher enjoyment towards the exergaming component. The results could be due to the nature of how exergames are played (the flow) by youth. Exergames usually start and stop depending on the mode being played, where a traditional aerobics class is often continuous. As an accelerometer measures PA intermittently, this may explain the differences seen in Moderate-to-Vigorous PA between the traditional aerobic and the exergaming conditions from the study. It has been hypothesized that children play exergames intermittently in physical education settings and home setting but consecutively in laboratory settings. At home, children may stop playing to give someone else a turn, or to play another game. In physical education settings there are usually warm ups, explanations and management by the instructors. In laboratory settings EE measured is typically from a constant

flow and minimizes non-activity time. Therefore, depending on the physical setting of where an exergame is being played, differences in EE and PA are observed.

Group versus individual - Playing exergames in a social setting has been shown to increase enjoyment, competence and self-efficacy[118] which in turn is associated with higher levels of moderate-to-vigorous PA. Several studies suggest that youth who play social games expend more energy than those who play alone [93]. This may contribute to differences in observed outcomes across highly controlled versus observational study designs.

Whole versus upper or lower body - Both activity intensity and EE are usually greater in exergames that involve the whole body including all four limbs, compared to games which use the upper or lower body only[64,123]. Game genre (i.e., dance, sports) is also important - most games elicit light-to-moderate PA, while dance and boxing exergames elicit more vigorous PA. Overall, exergames that require lower and full body movement produce higher amounts of EE, higher heart rates and higher VO2 max. Type of game played is well-controlled and measured in laboratory studies and RCTs while there is usually high variability across participants in observational studies. In addition to variability across participants, measurement of type of exergame played may be subject to recall issues in self-reports in observational studies.

Cooperative versus competitive - The type of exergame played influences exergame outcomes. As postulated by the self-determination theory[64], increases in EE and PA are typically observed when a participant is internally (intrinsically) motivated. Exergames that incorporate cooperative features produce higher intrinsic motivation than competitive games.[118] Higher motivation in turn increases EE, although people who enjoy competition also increase EE.[198,245] In addition to the body movements required to exergame, the nature of the challenge of the game is important. If a game is too challenging for a player, motivation decreases as does their level of play and vice versa. If an exergame is too easy, motivation and exertion decrease.[116,118] Most observational studies measure if the exergame is competitive or whether the player plays alone and could be a reason why PA and EE levels are not consistent with laboratory and intervention settings. Overall, competitive play increases EE and aggression in short bouts of exergaming,

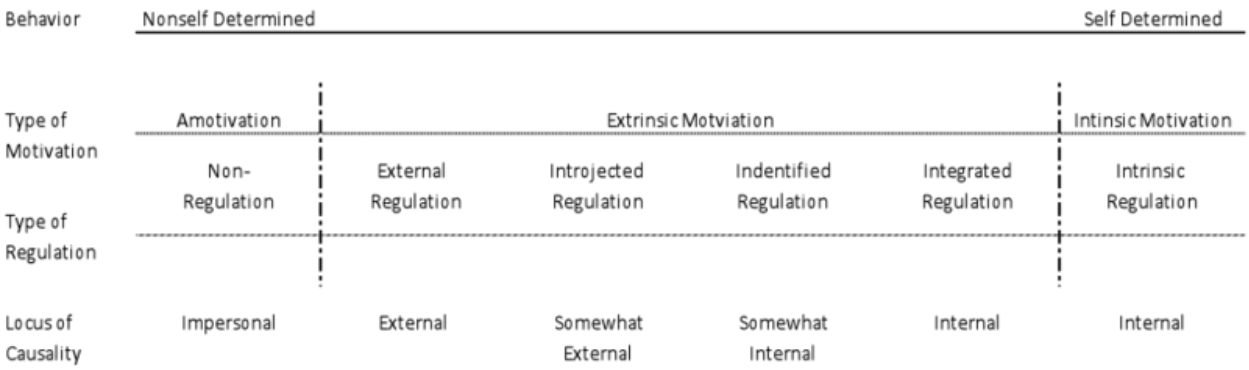
while cooperative exergaming increases motivation, promotes continued play, enhances self-efficacy, and increases pro-social behaviours [91].

Console - The console used in a particular study may contribute to the differences in exergaming outcomes observed across studies. Older consoles such as the original Wii by Nintendo require that players expend less energy than newer consoles such as the Kinect, the sportswalls found in exergame rooms, and Dance Dance Revolution[154]. The console and the exergame played is prescribed by the researchers in laboratory studies and RCTs, whereas observational studies do not prescribe the console used by participants. Further, observational studies do not usually measure or control for the console used.

Time spent exergaming- Length of time spent exergaming affects EE. Laboratory studies and RCTs usually test prescribed lengths of time per exergaming bout, with fixed rest periods between bouts. For example, Tan et al. (2002)[260] required participants to play Dance Dance Revolution for 10 minutes. Graeves et al. (2008)[60]studied 15-minute bouts of Wii sports, while Maddison et al. (2007)[215] asked participants to play each exergame for 5-8 minutes. These short prescribed time periods likely do not reflect how people use exergames in real life settings such as at home or in schools. Rather, observational studies will capture the length of time that people exergame in day-to-day living, which may contribute to the differences in outcomes observed across highly controlled versus observational studies.

APPENDIX C

Organismic Integration Theory Illustrated



(i) Not self-determined: represents the state of *amotivation* in that activities are not self-determined at all and there is no motivation to undertake a behaviour.

(ii) Partially self-determined: *External Regulation* which is the least motivated, where external rewards will not be internalized. *Introjected Regulation* is characterized by behaviours that are performed to avoid a sense of shame or guilt. It is a controlling form of behaviour regulation that has only been partially internalized. [94] *Identified Regulation* is when the behaviour is beginning to be accepted by the individual as valuable, and the behaviour begins to align with one's values, although not completely internalized.[96] *Integrated Regulation* is the most autonomous regulation among the external regulations although not fully internalized.

(iii) Self-determined: *Intrinsic motivation* is the most autonomous regulation in which behaviours align well with the individual's values and are performed because of inherent enjoyment.[99]

APPENDIX D

Barriers and Challenges Related to Exergaming[57]

1. Cost of equipment and consoles
2. Confidence in use of technology
3. Potential overuse
4. Constant evolution of technology
5. Boredom
6. Decreases in use over time
7. Technical problems
8. Injuries
9. Embarrassment and nervousness (when playing with others)
10. Less individuality with commercial games
11. Lack of emersion into the games

APPENDIX E

List of Articles Included in Abstract and Full Text Review and Reason for Exclusion (Study 1)

EBSCO search n=47	**Included in full text review yes/excluded (and reason for exclusion)**
Barnett, A., Cerin, E., & Baranowski, T. (2011). Active Videogames for Youth: A Systematic Review. *Journal Of Physical Activity & Health*, *8*(5), 724-737.	Yes
Barros, M., Neves, A., Correia, W., & Soares, M. (2012). Exergames: the role of ergonomics and design in helping to control childhood obesity through physical and functional exercise program. *Work (Reading, Mass.)*, *41 Suppl 1*1208-1211. doi:10.3233/WOR-2012-0644-1208	Excluded (not a review)
Best, J. R. (2013). Exergaming in youth: Effects on physical and cognitive health. *Zeitschrift Für Psychologie*, *221*(2), 72-78. doi:10.1027/2151-2604/a000137	Yes
Biddiss, E., & Irwin, J. (2010). Active videogames to promote physical activity in children and youth: a systematic review. *Archives Of Pediatrics & Adolescent Medicine*, *164*(7), 664-672. doi:10.1001/archpediatrics.2010.104	Yes
Bochner, R. E., Sorensen, K. M., & Belamarich, P. F. (2015). The Impact of Active Video Gaming on Weight in Youth: A Meta-Analysis. *Clinical Pediatrics*, *54*(7), 620-628. doi:10.1177/0009922814545165	Yes
Boulos, M. K. (2012). Xbox 360 Kinect exergames for health. *Games For Health*, (5), 326-330. doi:10.1089/g4h.2012.0041	Excluded (not a review)
Boulos, M. K., & Yang, S. P. (2013). Exergames for health and fitness: the roles of GPS and geosocial apps. *International Journal Of Health Geographics*, *12*18. doi:10.1186/1476-072X-12-18	Excluded (duplicate)
Brox, E., Fernandez-Luque, L., & Tøllefsen, T. (2011). Healthy Gaming - Videogame Design to promote Health. *Applied Clinical Informatics*, *2*(2), 128-142. doi:10.4338/ACI-2010-10-R-0060	Excluded (Reviewed how game design aspects apply to health games)
Carmo, J. F., & Palmeira, A. L. (2014). Can active videogames be part of the solution to promote physical activity in youth? A systematic review. *Archives Of Exercise In Health & Disease*, *4*, 216-226. doi:10.5628/aehd.v4i1.151	Yes
Chaput, J., LeBlanc, A. G., McFarlane, A., Colley, R. C., Thivel, D., Biddle, S. H., & ... Tremblay, M. S. (2013). Active Healthy Kids Canada's Position on Active Videogames for Children and Youth. *Paediatrics & Child Health (1205-7088)*, *18*(10), 529-532.	Excluded (not a review)
Chen, J., & Wilkosz, M. E. (2014). Efficacy of technology-based interventions for obesity prevention in adolescents: a systematic review. *Adolescent Health, Medicine And Therapeutics*, 5159-170. doi:10.2147/AHMT.S39969	Yes
Dutta, N., & Pereira, M. A. (2015). Effects of active videogames on energy expenditure in adults: A systematic literature review. *Journal Of Physical Activity & Health*, *12*(6), 890-899.	No (adults)
Foley, L., & Maddison, R. (2010). Use of Active Videogames to Increase Physical Activity in Children: A (Virtual) Reality?. *Pediatric Exercise Science*, *22*, 7-20.	Yes
Fontenele Lamboglia, C. G., da Silva, V. L., de Vasconcelos Filho, J. E., Pereira Pinheiro, M. N., da Silva Munguba, M. C., Silva Júnior, F. I., & ... da Silva, C. B. (2013). Exergaming as a Strategic Tool in the Fight against Childhood Obesity: A Systematic Review. *Journal Of Obesity*, *2013*1-8. doi:10.1155/2013/438364	Yes
Gao, Z., & Chen, S. (2014). Are field-based exergames useful in preventing childhood obesity? A systematic review. *Obesity Reviews*, *15*(8), 676-691. doi:10.1111/obr.12164	Yes
Gao, Z., Chen, S., Pasco, D., & Pope, Z. (2015). A meta-analysis of active videogames on health outcomes among children and adolescents. *Obesity Reviews*, *16*(9), 783-794. doi:10.1111/obr.12287	Yes
Gao, Z., Chen, S., Pasco, D., & Pope, Z. (2015). A meta-analysis of active videogames on health outcomes among children and adolescents. *Obesity Reviews*, *16*(9), 783-794. doi:10.1111/obr.12287	Excluded (duplicate)
Goldfield, G. S., Cameron, J. D., & Chaput, J. (2014). Is Exergaming a Viable Tool in the Fight against Childhood Obesity?. *Journal Of Obesity*, Yes-2. doi:10.1155/2014/304521	Excluded (not a review)
Guy, S., Ratzki-Leewing, A., & Gwadry-Sridhar, F. (2011). Moving beyond the stigma: systematic review of videogames and their potential to combat obesity. *International Journal Of Hypertension*, *2011*179124. doi:10.4061/2011/179124	Yes
Höchsmann, C., Schüpbach, M., & Schmidt-Trucksäss, A. (2016). Effects of Exergaming on Physical Activity in Overweight Individuals. *Sports Medicine*, *46*(6), 845-860. doi:10.1007/s40279-015-0455-z	Excluded (focused on specific population: adults and type 2 diabetes)
Höchsmann, C., Schüpbach, M., & Schmidt-Trucksäss, A. (2016). Effects of Exergaming on Physical Activity in Overweight Individuals. *Sports Medicine*, *46*(6), 845-860.	Excluded (duplicate)
Iglesia Molina, K., Aquaroni Ricci, N., Albuquerque de Moraes, S., & Rodrigues Perracini, M. (2014). Virtual reality using games for improving physical functioning in older adults: a systematic review. *Journal Of Neuroengineering & Rehabilitation (JN,ER)*, *11*)29. doi:10.1186/1743-0003-11-156	Excluded (focused on specific population: older adults)
Is Playing Exergames Really Exercising? A Meta-analysis of Energy Expenditure in Active Videogames. (2011). *Conference Papers -- International Communication Association*,19.	Excluded (not a review)

Kamel Boulos, M. N. (2012). Xbox 360 Kinect Exergames for Health. *Games For Health Journal*, (5), 326-330. doi:10.1089/g4h.2012.0041	Excluded (duplicate)
Kamel Boulos, M. N., & Yang, S. P. (2013). Exergames for health and fitness: the roles of GPS and geosocial apps. *International Journal Of Health Geographics*, *12*-7. doi:10.1186/1476-072X-12-18	Excluded (duplicate)
Kari, T. (2014). Can exergaming promote physical fitness and physical activity? A systematic review of systematic reviews. *International Journal Of Gaming And Computer-Mediated Simulations*, *6*(4), 59-77. doi:10.4018/ijgcms.2014100105	Excluded (Review of reviews)
Lamboglia, C. F., da Silva, V. L., de Vasconcelos Filho, J. E., Pinheiro, M. P., Munguba, M. S., Silva Júnior, F. I., & ... da Silva, C. B. (2013). Exergaming as a strategic tool in the fight against childhood obesity: a systematic review. *Journal Of Obesity*, *2013*438364. doi:10.1155/2013/438364	Excluded (duplicate)
LeBlanc, A. G., Chaput, J., McFarlane, A., Colley, R. C., Thivel, D., Biddle, S. H., & ... Tremblay, M. S. (2013). Active Videogames and Health Indicators in Children and Youth: A Systematic Review. *Plos ONE*, *8*(6)-20. doi:10.1371/journal.pone.0065351	Yes
LeBlanc, A. G., Larouche, R., Chaput, J., Goldfield, G. S., & Tremblay, M. S. (2014). No clear evidence that exergames can prevent obesity. *Obesity Reviews*, *15*(8), 692-693. doi:10.1111/obr.12192	Excluded (no abstract)
Li, J., Theng, Y., & Foo, S. (2016). Effect of Exergames on Depression: A Systematic Review and Meta-Analysis. *Cyberpsychology, Behavior & Social Networking*, *19*, 34-42.	Excluded (on older adults)
Li, J., Theng, Y., & Foo, S. (2016). Effect of Exergames on Depression: A Systematic Review and Meta-Analysis. *Cyberpsychology, Behavior And Social Networking*, *19*, 34-42. doi:10.1089/cyber.2015.0366	Excluded (duplicate)
Liang, Y., & Lau, P. C. (2014). Effects of Active Videogames on Physical Activity and Related Outcomes Among Healthy Children: A Systematic Review. *Games For Health Journal*, *3*(3), 122-144. doi:10.1089/g4h.2013.0070	Yes
Maddison, R., Straker, L., Palmeira, A., Simons, M., Witherspoon, L., & Thin, A. G. (2013). Active videogames—An opportunity for enhanced learning and positive health effects?. *Cognitive Technology*, *18*(Yes), 6-13.	Excluded (not a systematic or meta-analysis review)
Merino Campos, C. c., & del Castillo Fernández, H. h. (2016). The Benefits of Active Videogames for Educational and Physical Activity Approaches: A Systematic Review. *Journal Of New Approaches In Educational Research*, *5*(2), 115-122. doi:10.7821/naer.2016.7.164	Yes
Nirjhar, D., & Mark A., P. (2015). Effects of Active Videogames on Energy Expenditure in Adults: A Systematic Literature Review. *Journal Of Physical Activity & Health*, *12*(6), 890-899.	Excluded (duplicate)
Norris, E., Hamer, M., & Stamatakis, E. (2016). Active Videogames in Schools and Effects on Physical Activity and Health: A Systematic Review. *The Journal Of Pediatrics*, *172*40-46.e5. doi:10.1016/j.jpeds.2016.02.001	Excluded (school based review)
Okorodudu, D. E., Bosworth, H. B., & Corsino, L. (2015). Innovative interventions to promote behavioral change in overweight or obese individuals: A review of the literature. *Annals Of Medicine*, *47*(3), 179-185. doi:10.3109/07853890.2014.931102	Yes
Parisod, H., Pakarinen, A., Kauhanen, L., Aromaa, M., Leppänen, V., Liukkonen, T. N., & ... Salanterä, S. (2014). Promoting Children's Health with Digital Games: A Review of Reviews. *Games For Health Journal*, *3*(3), 145-156. doi:10.1089/g4h.2013.0086	Excluded (review of reviews)
Pasco, D., Bossard, C., Buche, C., & Kermarrec, G. (2011). Utiliser les Jeux Vidéos Actifs pour Promouvoir l'Activité Physique. *Sport Science Review*, *20*(2), 77-93.	Yes
Peng, W., Crouse, J. C., & Lin, J. (2013). Using Active Videogames for Physical Activity Promotion: A Systematic Review of the Current State of Research. *Health Education & Behavior*, *40*(2), 171-192. doi:10.1177/1090198112444956	Yes
Peng, W., Crouse, J. C., & Lin, J. (2013). Using Active Videogames for Physical Activity Promotion: A Systematic Review of the Current State of Research. *Health Education & Behavior*, *40*(2), 171-192.	Excluded (duplicate)
Peng, W., Lin, J., & Crouse, J. (2011). Is playing exergames really exercising? A meta-analysis of energy expenditure in active videogames. *Cyberpsychology, Behavior And Social Networking*, *14*(11), 681-688. doi:10.1089/cyber.2010.0578	Yes
Peng, W., Lin, J., & Crouse, J. (2011). Is Playing Exergames Really Exercising? A Meta-Analysis of Energy Expenditure in Active Videogames. *Cyberpsychology, Behavior & Social Networking*, *14*(11), 681-688. doi:10.1089/cyber.2010.0578	Excluded (duplicate)
Rahmani, E., & Boren, S. A. (2012). Videogames and health improvement: A literature review of randomized controlled trials. *Games For Health*, *Yes*(5), 331-340. doi:10.1089/g4h.2012.0031	Excluded (focused on educational setting)
Skip Rizzo, A., Lange, B., Suma, E. A., & Bolas, M. (2011). Virtual reality and interactive digital game technology: new tools to address obesity and diabetes. *Journal Of Diabetes Science And Technology*, *5*(2), 256-264.	Excluded (not a review)
Staiano, A. E., & Calvert, S. L. (2012). Digital Gaming and Pediatric Obesity: At the Intersection of Science and Social Policy. *Social Issues & Policy Review*, *6*, 54-81. doi:10.1111/j.1751-2409.2011.01035.x	Excluded (not a review)
Staiano, A. E., & Flynn, R. (2014). Therapeutic Uses of Active Videogames: A Systematic Review. *Games For Health Journal*, *3*(6), 351-365. doi:10.1089/g4h.2013.0100	Excluded (outcome not in criteria: Therapeutic use)
Sween, J., Wallington, S. F., Sheppard, V., Taylor, T., Llanos, A. A., & Adams-Campbell, L. L. (2014). The Role of Exergaming in Improving Physical Activity: A Review. *Journal Of Physical Activity & Health*, *11*(4), 864-870.	Yes
Tabak, M., Dekker-van Weering, M., van Dijk, H., & Vollenbroek-Hutten, M. (2015). Promoting Daily Physical Activity by Means of Mobile Gaming: A Review of the State of the Art. *Games For Health Journal*, *4*(6), 460-469. doi:10.1089/g4h.2015.0010	Yes
Vander Schee, C. J., & Boyles, D. (2010). 'Exergaming,' corporate interests and the crisis discourse of childhood obesity. *Sport, Education & Society*, *15*(2), 169-185. doi:10.1080/13573321003683828	Excluded (focus not just on educational setting)

van't Riet, J., Crutzen, R., & Lu, A. S. (2014). How effective are active videogames among the young and the old? Adding meta-analyses to two recent systematic reviews. *Games For Health*, *3*(5), 311-318. doi:10.1089/g4h.2014.0005	Yes
Witherspoon, L., & Manning, J. P. (2012). Active Gaming: The Future of Play?. *American Journal Of Play*, *4*(4), 464-487.	Excluded (not a review)
Witherspoon, L., & Manning, J. P. (2012). Active Gaming: The Future of Play?. *American Journal Of Play*, *4*(4), 464-487.	Excluded (duplicate)
Young, M. F., Slota, S., Cutter, A. B., Jalette, G., Mullin, G., Lai, B., & ... Yukhymenko, M. (2012). Our Princess Is in Another Castle: A Review of Trends in Serious Gaming for Education. *Review Of Educational Research*, *82*, 61-89. doi:10.3102/0034654312436980	Excluded (focus not just on educational setting)
Zeng, N., & Gao, Z. (2016). Exergaming and obesity in youth: current perspectives. *International Journal Of General Medicine*, *9*275-284. doi:10.2147/IJGM.S99025	Yes
Robertson-Wilson J, Reinders N, Bryden P. Dance Interventions to Increase Physical Activity Among Youth: A Systematic Review. Kinesiology Review [serial on the Internet]. (2016, Aug), 5(3): 170-188.	Excluded (focus not just on exergaming)
Additional Google scholar search n=6	
Siegel, Shannon R., et al. "Active video/arcade games (exergaming) and energy expenditure in college students." *International journal of exercise science* 2.3 (2009): 165.	Excluded (not a review)
Barton, Isabel. *The use of serious games and gamification within interventions for obese and overweight children and adolescents: a systematic review*. BS thesis. University of Twente, 2015.	Excluded (Bachelors thesis)
Lu, A.S., et al., *A systematic review of health videogames on childhood obesity prevention and intervention*. GAMES FOR HEALTH: Research, Development, and Clinical Applications, 2013. **2**(3): p. 131-141.	Yes
Warburton, Darren ER. "The health benefits of active gaming: separating the myths from the virtual reality." Current Cardiovascular Risk Reports 7.4 (2013): 251-255.	Excluded (not a systematic review or meta-analysis)
D Daley, A.J., *Can exergaming contribute to improving physical activity levels and health outcomes in children?* Pediatrics, 2009. **124**(2): p. 763-771.	Yes
Altamimi, R. and G. Skinner, *A survey of active videogame literature.* Journal of Computer and Information Technology, 2012. **1**(1): p. 20-35	Yes

n

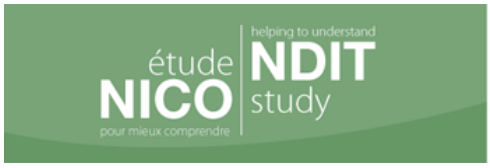
APPENDIX F

Variables Tested In Models Including Response Options, Coding For Analysis and Cronbach's Alpha For Scales (Study 2)

	Item(s)	Response choices/creation of score	Re-coded for analysis
Age	Date of birth, Date of survey		
Sex	Are you a boy or a girl?	Male, Female	Male, Female
Smoke cigarettes	Have you ever in your life smoked a cigarette, even just a puff (drag, hit, haul)?	No, yes	No, yes
Currently employed	Are you currently working at a job or business (paid or unpaid)?	No, yes	No, yes
Binge drink	In the past 6 months, how often did you …? Drink 5 or more alcoholic beverages on one occasion	Never, just once to try, once a month, 2-3 times per month, 1times per week, 2-3 times per week, 4-6 times per week, every day	No, yes
Marijuana use	In the past 6 months, how often did you …? Use marijuana, cannabis, hashish	Never, just once to try, once a month, 2-3 times per month, 1times per week, 2-3 times per week, 4-6 times per week, every day	No, yes
Paediatric daytime sleepiness scale (PDSS) (1) α =0.70	Usually, at what frequency do you…? (i)Fall asleep or feel drowsy while you're in class; (ii) Fall asleep or feel drowsy when you do your homework (iii) you're alert (awake) for the entire or almost the entire day (iv)You are tired and grumpy during most of the day (v) Do you have difficulties waking up in the morning? (vi) Do you fall back asleep when you are awake? (vii)Do you need someone to wake you up? (viii)Do you feel that you don't get enough sleep	1. Always 2. Often 3. Sometimes 4. Rarely 5. Never	Items were summed and divided by the number of items responded to create a score
Depressive symptoms (2-4) α = 0.82	During the past 7 days how often have you: (i) felt too tired to do things; (ii) had trouble going to sleep or staying asleep; (iii) felt unhappy, sad or depressed; (iv) felt hopeless about the future; (v) felt nervous or tense; (vi) worried too much about things	1. Never 2. Rarely 3. Sometimes 4. Often 5. Always	Items were summed and divided by the number of items responded to create a score
Perceived weight status	Do you consider yourself……	1. Too thin 2. Normal 3. A bit too large 4. Much too large	No, yes
Stress about weight	In your lifetime, have you ever been stressed about your…. Weight	1. Never 2. A little 3. Some 4. A lot 5. Does not apply	No, yes
Trying to lose weight	What are you actually trying to do about your weight?	1. Lose weight; 2. Gain weight; 3. Not trying to change my weight	No, yes
BMI	Self-report height and weight	BMI = kg/m2 where kg is a person's weight in kilograms and m2 is their height in metres squared.	As is
Hours of TV daily	On average, about how many hours a day do you watch TV or videos?	1. <1; 2. 1-2; 3. 3-4; 4. 5-6; 5. ≥7	≥ 0 <1 ≥1 <2 ≥2
Hours of computer daily	How many hours do you usually use the computer games, or use the Internet in a single day?	1. <1; 2. 1-2; 3. 3-4; 4. 5-6; 5. ≥7	≥ 0<1 ≥1<2 ≥2
Hours of non-active videogames daily	How many hours do you usually play games in a single day?	1. <1; 2. 1-2; 3. 3-4; 4. 5-6; 5. ≥7	0 <1 ≥1
Physical activity weekly (5)	Which one of the following describes you the best for a normal week? Read all 5 statements before deciding on the one that best describes you.	1. All or most of my free time is spent doing things that involve little physical effort; 2. I sometimes (1-2 times per week) do physical activities in my free time; 3. I often (3-4 times per week) do physical activities in my free time, 4. I quite often (5-6 times per week) do physical activities in my free time; 5. I very often (7 or more times) do physical activities in my free time.	As is

APPENDIX G

NDIT Questionnaire with Exergaming Behaviour Questions & RTEX Items



Survey Cycle: 23
By returning your completed questionnaire to us, **YOU CONSENT** to participate in the questionnaire component of the NDIT Study. If you do not wish to participate, please return the blank questionnaire to us, so that we know you have decided not to complete it. Thank you very much for your help!

Name: _____

ID:

1. What is today's date?

Day	Month	Year

2. What is your home postal code?

3. Do you currently live alone?

☐ Yes → **Go to question 5**
☐ No

4. Do you live with your…? Check all that apply.

	Yes
Biological mother	☐
Biological father	☐
Step-mother	☐
Step-father	☐
Sister(s), step-sister(s), half-sister(s)	☐
Brother(s), step-brother(s), half-brother(s)	☐
Husband, wife	☐

Partner (girlfriend, boyfriend)	☐
Son(s), step-son(s)	☐
Daughter(s), step-daughter(s)	☐
Roommate(s)	☐
Other (specify) _____	☐

5. Does this person currently smoke cigarettes? Your….

	Yes
Biological mother	☐
Biological father	☐
Step-mother	☐
Step-father	☐
Any sister, step-sister, half-sisters	☐
Any brother, step-brother, half-brother	☐
Husband, wife	☐
Partner (girlfriend, boyfriend)	☐
Any son, step-son	☐
Any daughter, step-daughter	☐
Any roommate	☐
Other (specify) _____	☐

6. How many close friends (people you feel at ease with and can talk to about what is on your mind) do you have?

_____ Close friends

7. How many of your close friends smoke cigarettes?

_____ Close friends smoke

8. Indicate your level of agreement with the following…

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I feel a bond with my close friends	☐	☐	☐	☐	☐
I feel that I am similar to my close friends	☐	☐	☐	☐	☐
I have a sense of belonging with my close friends	☐	☐	☐	☐	☐

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I have a lot in common with my close friends	☐	☐	☐	☐	☐

9. Even if you do not currently smoke cigarettes, how often do you…?

	Never	Rarely	Sometimes	Often
Want to smoke a cigarette	☐	☐	☐	☐
Need a cigarette	☐	☐	☐	☐
Crave a cigarette	☐	☐	☐	☐

10. Even if you do not currently smoke cigarettes, how addicted to smoking cigarettes are you…?

	Not at all	A little bit	Quite	Very
Physically	☐	☐	☐	☐
Mentally	☐	☐	☐	☐

11. Have you ever in your life smoked a cigarette, even just a puff (drag, hit, haul)?

☐ No → **Go to question 43**
☐ Yes, 1 or 2 times
☐ Yes, 3 or 4 times
☐ Yes, 5 to 10 times
☐ Yes, more than 10 times

12. Check the box that describes you best…

☐ I have smoked cigarettes, but not at all in the past 12 months
☐ I smoked cigarettes once or a couple of times in the past 12 months
☐ I smoke cigarettes once or a couple of times each month
☐ I smoke cigarettes once or a couple of times each week
☐ I smoke cigarettes every day

13. Have you smoked 100 or more whole cigarettes (4 packs of 25) in your life?

☐ No
☐ Yes

14. How old were you when you took cigarette smoke into your lungs for more than one puff?

I was _____ years old
☐ I have never done this

15. Did you smoke cigarettes (even just a puff) in the past three months?

☐ No → **Go to question 22**
☐ Yes

16. During _____ (last month), on how many days did you smoke cigarettes, even just a puff?

- ☐ None → **Go to question 18**
- ☐ 1 day
- ☐ 2-3 days
- ☐ 4-5 days
- ☐ 6-10 days
- ☐ 11-15 days
- ☐ 16-20 days
- ☐ 21-30 days
- ☐ Every day
- ☐ Don't know

17. On the days that you smoked during _____ (last month), how many cigarettes did you usually smoke each day?

- ☐ Less than 1 cigarette (one or a few puffs)
- ☐ 1 cigarette
- ☐ 2-3 cigarettes
- ☐ 4-5 cigarettes
- ☐ 6-10 cigarettes
- ☐ 11-15 cigarettes
- ☐ 16-20 cigarettes
- ☐ 21-25 cigarettes
- ☐ More than 25
- ☐ Don't know

18. During _____ (2 months ago), on how many days did you smoke cigarettes, even just a puff?

- ☐ None → **Go to question 20**
- ☐ 1 day
- ☐ 2-3 days
- ☐ 4-5 days
- ☐ 6-10 days
- ☐ 11-15 days
- ☐ 16-20 days
- ☐ 21-30 days
- ☐ Every day
- ☐ Don't know

19. On the days that you smoked during _____ (2 months ago), how many cigarettes did you usually smoke each day?

- ☐ Less than 1 cigarette (one or a few puffs)
- ☐ 1 cigarette
- ☐ 2-3 cigarettes
- ☐ 4-5 cigarettes
- ☐ 6-10 cigarettes
- ☐ 11-15 cigarettes
- ☐ 16-20 cigarettes
- ☐ 21-25 cigarettes
- ☐ More than 25
- ☐ Don't know

20. During _____ (3 months ago), on how many days did you smoke cigarettes, even just a puff?

- ☐ None → **Go to question 22**
- ☐ 1 day
- ☐ 2-3 days
- ☐ 4-5 days
- ☐ 6-10 days
- ☐ 11-15 days
- ☐ 16-20 days
- ☐ 21-30 days
- ☐ Every day
- ☐ Don't know

21. On the days that you smoked during _____ (3 months ago), how many cigarettes did you usually smoke each day?

- ☐ Less than 1 cigarette (one or a few puffs)
- ☐ 1 cigarette
- ☐ 2-3 cigarettes
- ☐ 4-5 cigarettes
- ☐ 6-10 cigarettes
- ☐ 11-15 cigarettes
- ☐ 16-20 cigarettes
- ☐ 21-25 cigarettes
- ☐ More than 25
- ☐ Don't know

22. Do you smoke cigarettes now because it is really hard to quit?

- ☐ No
- ☐ Sometimes
- ☐ Often/always
- ☐ Never tried to quit
- ☐ Other (please explain) _____
- ☐ Don't know (I smoke so little)

23. When you cut down or stop using cigarettes, or when you are not able to smoke for a long period (like most of the day), how often do you experience…?

	Never	Rarely	Sometimes	Often
Feeling irritable or angry	☐	☐	☐	☐
Feeling restless	☐	☐	☐	☐
Feeling nervous, anxious, or tense	☐	☐	☐	☐
Trouble concentrating	☐	☐	☐	☐
Feeling a strong urge or need to smoke	☐	☐	☐	☐
Trouble sleeping	☐	☐	☐	☐

24. How well do each of the following describe you?

	Describes me…			
	Not at all	A little	Pretty well	Very well
If I go too long without a cigarette, I begin to feel angry or irritable	☐	☐	☐	☐
If I go too long without a cigarette, I feel stressed	☐	☐	☐	☐
I usually want to smoke or use dip right after I wake up	☐	☐	☐	☐
If I go too long without smoking, the first thing I notice is a mild desire to smoke that I can ignore	☐	☐	☐	☐
If I go too long without smoking, the desire for a cigarette becomes so strong that it is hard to ignore and it interrupts my thinking	☐	☐	☐	☐

If I go too long without smoking, I just can't function right, and I know I will have to smoke just to feel normal again	☐	☐	☐	☐

25. When you see other people smoking cigarettes, how easy is it for you not to smoke?

- ☐ Very easy
- ☐ Quite easy
- ☐ A bit difficult
- ☐ Very difficult

26. How long can you go without smoking a cigarette before you feel a strong desire to smoke that is hard to ignore?

- ☐ Less than an hour
- ☐ 1-2 hours
- ☐ 3-5 hours
- ☐ 6-10 hours
- ☐ 11-15 hours
- ☐ 16-23 hours
- ☐ 1 day
- ☐ 2 days
- ☐ More than 2 days, less than a week
- ☐ A week or more
- ☐ Other (specify) _____

27. How deeply do you usually inhale?

- ☐ Just into my mouth
- ☐ Back into my throat
- ☐ Into my lungs shallow
- ☐ Into my lungs deep
- ☐ Don't know (I smoke so little)

28. On the days that you smoke, how soon after you wake up do you smoke your first cigarette?

- ☐ Within 5 minutes
- ☐ 6 - 30 minutes after waking
- ☐ 31 - 60 minutes after waking
- ☐ More than 60 minutes after waking

29. Do you find it difficult to refrain from smoking in places where it is forbidden?

- ☐ Not at all difficult
- ☐ A bit difficult
- ☐ Very difficult

30. Do you smoke more frequently during the first hours after waking, compared with the rest of the day?

- ☐ No

☐ Yes

31. If you are sick with a bad cold or sore throat, do you smoke?

☐ No, I stop smoking when I'm sick
☐ Yes, but I cut down on the amount I smoke
☐ Yes, I smoke the same amount as when I'm not sick

32. How true is each of the following for you?

	Not at all true	A bit true	Very true
Cigarettes are good for dealing with boredom	☐	☐	☐
A cigarette gives me energy when I'm tired	☐	☐	☐
When I'm feeling down, a cigarette makes me feel good	☐	☐	☐
Smoking cigarettes calms me down when I feel nervous	☐	☐	☐
Smoking cigarettes helps me control my weight	☐	☐	☐
Smoking cigarettes helps me concentrate on my work/homework	☐	☐	☐
Smoking cigarettes relieves tension when I am stressed	☐	☐	☐
I consider myself to be a social smoker	☐	☐	☐
I avoid going to a friend's house where you're not allowed to smoke even though I might enjoy hanging out with him/her	☐	☐	☐
In situations where I need to go outside to smoke, it's worth it even in cold or rainy weather	☐	☐	☐
I have cut down or stopped physical activities or sports because of my smoking	☐	☐	☐
I can function much better in the morning after I've had a cigarette	☐	☐	☐
Compared to when I first started smoking, I need to smoke a lot more now to be satisfied	☐	☐	☐
Compared to when I first started smoking, I can smoke much more now before I start to feel nauseated or ill **OR** ☐ I've never felt nauseated or ill from smoking	☐	☐	☐
I often run out of cigarettes quicker than I thought I would	☐	☐	☐
I spend a lot of time getting cigarettes (going out of my way to buy cigarettes)	☐	☐	☐
I spend a lot of time smoking cigarettes (chain smoking, smoking a lot throughout the day)	☐	☐	☐
I've stopped hanging out with certain people because of my smoking	☐	☐	☐

33. How often do you have cravings to smoke cigarettes?

☐ Never → **Go to question 35**
☐ Very rarely
☐ Sometimes
☐ Often
☐ Very often

34. How strong are your cravings to smoke cigarettes?

- ☐ Not at all strong
- ☐ A bit strong
- ☐ Quite strong
- ☐ Very strong

35. Which cigarette would you most hate to give up?

- ☐ The first one of the day
- ☐ Another one
- ☐ Don't know (I smoke so little)

36. At this point in time, how much do you really want to quit smoking cigarettes completely and forever?

- ☐ Not at all
- ☐ A little bit
- ☐ Quite a bit
- ☐ A whole lot

37. In the last 12 months, did you seriously try to quit smoking cigarettes completely and forever?

- ☐ No
- ☐ Yes, once
- ☐ Yes, two or more times

38. When was the last time you made a serious attempt to quit smoking cigarettes?

- ☐ Never made a serious attempt to quit smoking

_____ day(s) ago
_____ month(s) ago
_____ year(s) ago

39. How confident are you that you can or that you have quit smoking cigarettes completely and forever?

- ☐ Very confident
- ☐ Fairly confident
- ☐ Not very confident
- ☐ Not at all confident

40. Think about the last time you tried to quit smoking cigarettes. Did you quit smoking completely (for a while)?

- ☐ Never tried to quit
- ☐ No, but I cut down a lot
- ☐ No, but I cut down a little
- ☐ No, the amount I smoke didn't change at all
- ☐ Yes → I quit completely for _____days
- ☐ Yes → I quit completely and have remained non-smoking ever since

41. How true for you are each of the following reasons to quit smoking cigarettes?

	Not at all true	A little true	Moderately true	Quite true	Extremely true
Because I am concerned that I will suffer from a serious illness if I don't quit smoking	☐	☐	☐	☐	☐
To show myself that I can quit smoking if I really want to	☐	☐	☐	☐	☐
So that my hair and clothes won't smell	☐	☐	☐	☐	☐
So that my spouse, children, or another person I am close to will stop nagging me	☐	☐	☐	☐	☐
Because I have noticed physical symptoms that smoking is hurting my health	☐	☐	☐	☐	☐
Because I will like myself better if I quit smoking	☐	☐	☐	☐	☐
So that I will save money on smoking-related costs such as dry cleaning	☐	☐	☐	☐	☐
Because someone has given me an ultimatum to quit (made a threat)	☐	☐	☐	☐	☐
Because I can graphically picture the effects that smoking has on my body	☐	☐	☐	☐	☐
So that I can feel in control of my life	☐	☐	☐	☐	☐
Because I won't burn holes in clothing or furniture	☐	☐	☐	☐	☐
Because I will receive a special gift if I quit	☐	☐	☐	☐	☐
Because I know other people who have died from serious illnesses caused by smoking	☐	☐	☐	☐	☐
Because quitting smoking will prove that I can accomplish other things that are important to me	☐	☐	☐	☐	☐
Because I want to save the money that I spend on cigarettes	☐	☐	☐	☐	☐
Because people I am close to will be upset with me if I don't quit	☐	☐	☐	☐	☐
Because I am concerned that smoking will shorten my life	☐	☐	☐	☐	☐
To prove to myself that I am not addicted to cigarettes	☐	☐	☐	☐	☐
So that I won't have to clean my house or car as often	☐	☐	☐	☐	☐
Because I will receive a financial reward (money from a friend or family member, bonus from work) for quitting	☐	☐	☐	☐	☐
Because I want to set a good example for my children	☐	☐	☐	☐	☐
Because I (or my partner) is pregnant or planning to become pregnant	☐	☐	☐	☐	☐
Because my doctor advised me to quit smoking	☐	☐	☐	☐	☐

42. Did you ever try any of the following to help you quit smoking cigarettes? If yes, was this in the past 12 months? Did it help you to quit?

	Ever tried Yes	Tried in the past 12 months Yes	Helped me quit Yes
Nicotine patch	☐	☐	☐
Nicotine gum (Nicorette)	☐	☐	☐
Nicotine inhaler	☐	☐	☐
Zyban, Wellbutrin, Bupropion	☐	☐	☐
Varenicline (Champix)	☐	☐	☐
Electronic cigarettes with nicotine	☐	☐	☐
Electronic cigarettes without nicotine	☐	☐	☐
Cold Turkey	☐	☐	☐
Cutting down by only smoking at certain times or in certain situations	☐	☐	☐
Not having cigarettes with me (threw them out)	☐	☐	☐
Using other drugs (alcohol, marijuana, sleeping pills) more often	☐	☐	☐
Spending more time with friends who don't smoke	☐	☐	☐
Keeping myself occupied by doing other things	☐	☐	☐
Using a quit smoking APP	☐	☐	☐
Using a quit smoking SMS program (SMAT)	☐	☐	☐
Other (specify) _____	☐	☐	☐

43. Are there any restrictions on smoking cigarettes in your home? Check all that apply.

☐ No; smoking is permitted anywhere in my home anytime
☐ Yes; smoking is not permitted at all inside my home
☐ Yes; smoking is permitted in certain rooms only
☐ Yes; smoking is restricted in the presence of children
☐ Yes; other (specify) _____

44. Are there any restrictions on smoking cigarettes in your car or in the car you travel in most often? Check all that apply.

☐ No; smoking is permitted anytime
☐ Yes; smoking is not permitted at all in the car
☐ Yes; smoking is not permitted when there are children in the car
☐ Not applicable (I do not/infrequently travel by car)

45. How many people smoke cigarettes inside your home every day or almost every day?

☐ None OR _____ people

46. In the past month, how often were you exposed to second-hand smoke...?

	Never	Rarely	Sometimes	Fairly often	Very often
Inside your home	☐	☐	☐	☐	☐
In a car or other private vehicle	☐	☐	☐	☐	☐
Inside public places (bars, restaurants, shopping malls, arenas)	☐	☐	☐	☐	☐
When visiting the homes of friends or relatives	☐	☐	☐	☐	☐
Outside a restaurant on a patio or terrace	☐	☐	☐	☐	☐
At work	☐	☐	☐	☐	☐
At school	☐	☐	☐	☐	☐
Other (specify)_____	☐	☐	☐	☐	☐

47. In the past 12 months, how many organized sports teams did you belong to (where you practice with teammates or play against other teams)?

☐ None OR _____ teams

48. In the last 7 days, on how many days did you do <u>vigorous</u> physical activities (heavy lifting, digging, aerobics, fast bicycling) for at least 10 minutes at a time?

☐ None → **Go to question 50**

_____ days in the last 7 days

49. On the days that you did <u>vigorous</u> physical activities, how many minutes did you usually spend per day?

_____ minutes per day

50. In the last 7 days, on how many days did you do <u>moderate</u> physical activities (carrying light loads, bicycling at a regular pace, doubles tennis) for at least 10 minutes? Do not include walking.

☐ None → **Go to question 52**

_____ days in the last 7 days

51. On the days that you did <u>moderate</u> physical activities, how many minutes did you usually spend per day?

_____ minutes per day

52. In the last 7 days, on how many days did you walk for at least 10 minutes at a time?

☐ None → **Go to question 54**

_____ days in the last 7 days

53. On the days that you walked, how many minutes did you usually spend walking per day?

_____ minutes per day

54. To what extent is each of the following true for you?

	Not true	Rarely true	Sometimes true	Often true	Very often true
It's important to me to exercise regularly	☐	☐	☐	☐	☐
I don't see why I should have to exercise	☐	☐	☐	☐	☐
I exercise because it's fun	☐	☐	☐	☐	☐
I feel guilty when I don't exercise	☐	☐	☐	☐	☐
I exercise because it's consistent with my life goals	☐	☐	☐	☐	☐
I exercise because other people say I should	☐	☐	☐	☐	☐
I value the benefits of exercise	☐	☐	☐	☐	☐
I can't see why I should bother exercising	☐	☐	☐	☐	☐
I enjoy my exercise sessions	☐	☐	☐	☐	☐
I feel ashamed when I miss an exercise session	☐	☐	☐	☐	☐
I consider exercise part of my identity	☐	☐	☐	☐	☐
I take part in exercise because my friends/family/partner say I should	☐	☐	☐	☐	☐
I think it's important to make the effort to exercise regularly	☐	☐	☐	☐	☐
I don't see the point in exercising	☐	☐	☐	☐	☐
I find exercise a pleasurable activity	☐	☐	☐	☐	☐
I feel like a failure when I haven't exercised in a while	☐	☐	☐	☐	☐
I consider exercise a fundamental part of who I am	☐	☐	☐	☐	☐
I exercise because others will not be pleased with me if I don't	☐	☐	☐	☐	☐
I get restless if I don't exercise regularly	☐	☐	☐	☐	☐
I think exercising is a waste of time	☐	☐	☐	☐	☐
I get pleasure and satisfaction from participating in exercise	☐	☐	☐	☐	☐
I would feel bad about myself if I was not making time to exercise	☐	☐	☐	☐	☐
I consider exercise consistent with my values	☐	☐	☐	☐	☐
I feel under pressure from my friends/family to exercise	☐	☐	☐	☐	☐

55. How true are each of the following for you? When I exercise, I feel like…

	False	Mostly false	More false than true	More true than false	Mostly true	True
I engage in a variety of exercises	☐	☐	☐	☐	☐	☐
I try a range of exercises	☐	☐	☐	☐	☐	☐
I change the type of exercise that I do	☐	☐	☐	☐	☐	☐
My exercise program is varied	☐	☐	☐	☐	☐	☐
I experience variety in my exercise	☐	☐	☐	☐	☐	☐

56. How many of your close friends …?

	None	A few	Some	Most	All
Exercise most days of the week	☐	☐	☐	☐	☐
Are physically active	☐	☐	☐	☐	☐

57. How important is it for your close friends to…?

	Not very important	Somewhat important	Very important
Exercise most days of the week	☐	☐	☐
Be physically active	☐	☐	☐

58. Indicate your level of agreement with the following. My close friends …

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Encourage me to be physically active	☐	☐	☐	☐	☐
Would disapprove if they saw me just sitting around	☐	☐	☐	☐	☐
Think I should exercise most days of the week	☐	☐	☐	☐	☐
Think I should be physically active	☐	☐	☐	☐	☐

59. During one hour of sitting in a typical 7-hour (work)day, how many breaks from sitting (standing up, stretching, taking a short walk) do you usually take? Write "0" if you usually do not take any breaks.

_____ break(s)

60. In a typical 7-hour (work)day, how many minutes do you spend in short physical activity breaks? Write "0" if you usually do not take any breaks.

_____ minute(s)

61. Which statement best describes your usual daily activities or work habits in the past 3 months?

- ☐ Usually sit during the day and don't walk around very much
- ☐ Stand or walk quite a lot during the day but don't have to carry or lift things very often
- ☐ Usually lift or carry light loads, or have to climb stairs or hills often
- ☐ Do heavy work or carry very heavy loads

62. Do you consider yourself….?

- ☐ Too thin
- ☐ Just about right
- ☐ A little too heavy
- ☐ Much too heavy

63. How much do you weigh?

_____ pounds **OR** _____ kilograms

64. How tall are you without your shoes on?

____ feet ____inches **OR** ____ meters ____cm

65. Currently, what are you doing about your weight?

- ☐ I'm trying to lose weight
- ☐ I'm trying to gain weight
- ☐ I want to maintain my weight
- ☐ I'm not doing anything about my weight

66. Are you or your partner currently pregnant?

- ☐ No/Not applicable → **Go to question 68**
- ☐ Yes, I am pregnant
- ☐ Yes, my partner is pregnant

67. How many weeks pregnant are you or your partner?

_____ week(s) pregnant

68. How often do you overeat (eat more than usual, more than you wanted, more than you think is good for you)?

- ☐ Never → **Go to question 70**
- ☐ Rarely
- ☐ Sometimes
- ☐ Often

☐ Very often

69. Do you do any of the following to compensate for overeating during the 24 hours after overeating?

	Never	Rarely	Sometimes	Often	Very often
Exercise or go for a walk	☐	☐	☐	☐	☐
Purge (vomit) or use laxatives	☐	☐	☐	☐	☐
Skip meals	☐	☐	☐	☐	☐
Give up on my diet for the rest of the day	☐	☐	☐	☐	☐
Eat fruits	☐	☐	☐	☐	☐
Eat vegetables	☐	☐	☐	☐	☐
Eat more high-protein foods	☐	☐	☐	☐	☐
Eat fewer fried foods	☐	☐	☐	☐	☐
Eat fewer sweets	☐	☐	☐	☐	☐
Eat foods that are low in calories	☐	☐	☐	☐	☐
Eat more because I blew my diet for the day	☐	☐	☐	☐	☐
Do nothing differently	☐	☐	☐	☐	☐

70. In the past 2 years, how often did people in your life…?

	Never	Rarely	Sometimes	Often	Always
Make negative comments about your weight	☐	☐	☐	☐	☐
Encourage you to lose weight	☐	☐	☐	☐	☐
Encourage you to gain weight	☐	☐	☐	☐	☐

71. How many hours per day do you usually spend in front of a screen (computer, hand-held device) for work or for school? Write "0" if none. Write "LT ½" if less than ½ hour.

On weekdays, I usually spend _____ hour(s) per day in front of a screen for work or school

On weekends, I usually spend _____ hour(s) per day in front of a screen for work or school

72. How many hours per day, during your leisure time, do you usually spend in front of a screen (computer, TV, hand-held device)? Write "0" if none. Write "LT ½" if less than ½ hour.

On weekdays, I usually spend _____ hour(s) per day in front of a screen in my leisure time

On weekends, I usually spend _____ hour(s) per day in front of a screen in my leisure time

73. How many minutes per day do you usually spend on social media (Facebook, Twitter, Instagram, Snapchat) posting or browsing? Write "0" if none. Write "LT ½" if less than ½ hour.

On weekdays, I usually spend_____ minute(s) per day posting or browsing on social media

On weekends, I usually spend _____ minute(s) per day posting or browsing on social media

74. How many times per day OR per week OR per month (ANSWER ONLY ONE) do you eat or drink the following foods?

	Never		Times per day		Times per week		Times per month
Donuts or cakes or pastries	☐	or		or		or	
Candy or chocolate bars	☐	or		or		or	
Ice cream/frozen yogurt	☐	or		or		or	
Potato chips, Fritos, Doritos	☐	or		or		or	
Diet soft drinks	☐	or		or		or	
Regular soft drinks	☐	or		or		or	
Deli or charcuterie meats	☐	or		or		or	
Fried chicken (Kentucky)	☐	or		or		or	
Hot dogs	☐	or		or		or	
Hamburgers	☐	or		or		or	
French fries or poutine	☐	or		or		or	
Bacon or sausages	☐	or		or		or	
100% fruit juice (orange, grapefruit, or tomato juice)	☐	or		or		or	
Fruit (not including juice)	☐	or		or		or	
Green salad	☐	or		or		or	
Potatoes (not including French fries, fried potatoes, potato chips)	☐	or		or		or	
Carrots	☐	or		or		or	
Other vegetables (not including carrots, potatoes, green salad)	☐	or		or		or	
Walnuts, seeds or other nuts and nut butters (including peanuts or peanut butter)	☐	or		or		or	
Milk (including chocolate milk, hot chocolate, café au lait, in cereal)	☐	or		or		or	
Milk alternatives (almond, soy, rice)	☐	or		or		or	
Yogurt, kefir, excluding frozen yogurt	☐	or		or		or	
Processed cheese slices or spreads (Kraft slices, Vache Qui Rit, Cheez Wiz, Velveeta)	☐	or		or		or	

	Never		Times per day		Times per week		Times per month
Other cheeses	☐	or		or		or	
Cereal (hot or cold)	☐	or		or		or	
Rice and other grains (quinoa)	☐	or		or		or	
Pasta, couscous	☐	or		or		or	
Bread, bagels, pita, tortilla wraps	☐	or		or		or	
Red Meat (beef, pork, lamb, horse, veal)	☐	or		or		or	
Chicken/poultry	☐	or		or		or	
Fresh/frozen fish and fish products (canned tuna)	☐	or		or		or	
Seafood (shrimp, lobster, scallops)	☐	or		or		or	
Tofu, Veggie burgers, Veggie hot dogs, TVP	☐	or		or		or	
Eggs and egg dishes	☐	or		or		or	
Cooked/canned dried peas, lentils, beans, Falafel, Hummus	☐	or		or		or	
Pizza (frozen, fast-food or delivery)	☐	or		or		or	
Frozen meals	☐	or		or		or	
Tea and tisanes	☐	or		or		or	
Coffee	☐	or		or		or	

75. Have you ever exergamed (played an active videogame) that uses a console (Nintendo WII, XBOX 360, Kinect, Sony Play Station Move, Sony Eye Toy: Kinetic), a cell phone or a mobile APP (RUN!, Nike+ Running APP, Pokémon Go)?

☐ No→ **Go to question 83**

☐ Yes

76. In the past 12 months, how often did you exergame…?

	Never	Less than once a month	1-3 times per month	1-3 times a week	4-6 times per week	Every day
Using a console	☐	☐	☐	☐	☐	☐
Using a cellphone or mobile APP	☐	☐	☐	☐	☐	☐

77. In the past month, how many days per week did you exergame?

☐ None → **Go to question 80**

_____ days per week

78. On average, how many minutes did you spend each time you exergamed?

_____ minutes on average

79. In the past month, what was your usual level of effort when you exergamed?

☐ Light
☐ Moderate
☐ Intense

80. How true is each of the following for you?

	Completely false	Slightly false	Neither true nor false	Slightly True	Completely true
I like to exergame	☐	☐	☐	☐	☐
I prefer exergaming over outdoor sports	☐	☐	☐	☐	☐
I prefer exergaming over indoor sports	☐	☐	☐	☐	☐
I like to exergame with friends	☐	☐	☐	☐	☐
I like to exergame with my family	☐	☐	☐	☐	☐
I think that exergaming is a good way to integrate physical activity into my life	☐	☐	☐	☐	☐
I think that I will exergame for many years	☐	☐	☐	☐	☐
Given the chance I would exergame in my free time	☐	☐	☐	☐	☐
Exergaming is boring	☐	☐	☐	☐	☐
I prefer exergaming over traditional videogames	☐	☐	☐	☐	☐
Exergames are irritating to play	☐	☐	☐	☐	☐
Exergames are calming to play	☐	☐	☐	☐	☐
I prefer exergaming over watching TV	☐	☐	☐	☐	☐
I prefer exergaming over being on social media (facebook, instagram, snapchat)	☐	☐	☐	☐	☐
Exergaming is exciting	☐	☐	☐	☐	☐
I exergame to be more active	☐	☐	☐	☐	☐
I exergame to lose weight	☐	☐	☐	☐	☐
I exergame to maintain my weight	☐	☐	☐	☐	☐
I exergame to maintain my level of fitness	☐	☐	☐	☐	☐
I exergame to gain strength	☐	☐	☐	☐	☐
I exergame to “bulk up”	☐	☐	☐	☐	☐
I exergame to gain flexibility	☐	☐	☐	☐	☐
I exergame to gain balance	☐	☐	☐	☐	☐
I exergame just for fun	☐	☐	☐	☐	☐

I exergame to be social	☐	☐	☐	☐	☐
Exergaming is the only type of videogame I like	☐	☐	☐	☐	☐
Videogames other than exergames bore me	☐	☐	☐	☐	☐

81. How often do you exergame…?

	Never	Rarely	Sometimes	Often	Very often
Alone	☐	☐	☐	☐	☐
With friends	☐	☐	☐	☐	☐
With family	☐	☐	☐	☐	☐

82. How important are the following in motivating you to continue exergaming…?

	Very important	Important	Neither important nor unimportant	Unimportant	Very unimportant
I am able to play well	☐	☐	☐	☐	☐
The game gets harder as you progress	☐	☐	☐	☐	☐
The goal of the game (winning, scoring high point totals) is easy to understand	☐	☐	☐	☐	☐
Tips in the game help me play better	☐	☐	☐	☐	☐
The game provides feedback on how to improve my play	☐	☐	☐	☐	☐
I like the sound effects in the game	☐	☐	☐	☐	☐
I feel like I am really part of what is happening	☐	☐	☐	☐	☐
The game is addictive	☐	☐	☐	☐	☐
I lose track of time while playing	☐	☐	☐	☐	☐
The game provides interesting options and choices	☐	☐	☐	☐	☐
I try to figure out new ways to play the game	☐	☐	☐	☐	☐
I feel like I can control what is happening	☐	☐	☐	☐	☐
Learning the game controls (Wii-mote, Kinect, PS Move) is easy	☐	☐	☐	☐	☐
I feel like my movements control the game	☐	☐	☐	☐	☐
The game is challenging	☐	☐	☐	☐	☐
The game keeps me on my toes, but does not overwhelm me	☐	☐	☐	☐	☐
The game includes challenges within each level	☐	☐	☐	☐	☐

	Very important	Important	Neither important nor unimportant	Unimportant	Very unimportant
I know what I have to do to win	☐	☐	☐	☐	☐
The game provides feedback on how I am doing	☐	☐	☐	☐	☐
I am able to practice skills within a game, which helps me play better	☐	☐	☐	☐	☐
I like the graphics	☐	☐	☐	☐	☐
I discover new things about the game the more I play	☐	☐	☐	☐	☐
I find myself getting totally absorbed in the game	☐	☐	☐	☐	☐
The game allows me to do interesting things	☐	☐	☐	☐	☐
I am able to play the game the way I want to	☐	☐	☐	☐	☐
The game controller (tennis racquet, bowling ball) tracks my movements well	☐	☐	☐	☐	☐
If I want to do something in the game, it is easy to remember the correct control (Wii-mote, Kinect, PS Move)	☐	☐	☐	☐	☐

83. In general, how would you rate…?

	Poor	Fair	Good	Very good	Excellent
Your health	☐	☐	☐	☐	☐
Your mental health	☐	☐	☐	☐	☐
Your ability to handle unexpected and difficult problems (a family or personal crisis)	☐	☐	☐	☐	☐
Your ability to handle day-to-day demands in your life (work, family responsibilities)	☐	☐	☐	☐	☐
The overall quality of your sleep at night	☐	☐	☐	☐	☐
The quality of your sleep in the past month	☐	☐	☐	☐	☐

84. How often do you feel…?

	Never	Rarely	Sometimes	Often	Always
Ashamed of the way you look	☐	☐	☐	☐	☐
Proud that you are more attractive than others	☐	☐	☐	☐	☐
Proud that you are a good-looking person	☐	☐	☐	☐	☐
Inadequate when you think about your appearance	☐	☐	☐	☐	☐
Ashamed of your appearance	☐	☐	☐	☐	☐
Proud of your superior appearance	☐	☐	☐	☐	☐
Proud of the effort you place on maintaining your appearance	☐	☐	☐	☐	☐
Proud of your efforts to improve the way you look	☐	☐	☐	☐	☐
Proud that you have achieved your appearance goals	☐	☐	☐	☐	☐
Proud of your appearance efforts	☐	☐	☐	☐	☐
Ashamed that you are a person who is unattractive	☐	☐	☐	☐	☐
Guilty that you do not do enough to improve the way you look	☐	☐	☐	☐	☐
Guilty that you look the way you do	☐	☐	☐	☐	☐
Regret that you do not work on improving your appearance	☐	☐	☐	☐	☐
Regret that you do not put effort into your appearance	☐	☐	☐	☐	☐
Proud that you are an attractive person	☐	☐	☐	☐	☐
Envious of another person’s appearance	☐	☐	☐	☐	☐
Inferior when you think about your appearance	☐	☐	☐	☐	☐
Frustrated to see some people who have a great appearance with little effort	☐	☐	☐	☐	☐
Unfair that some people have the “perfect” appearance	☐	☐	☐	☐	☐
Embarrassed about your appearance	☐	☐	☐	☐	☐
Foolish when your body and appearance are on display	☐	☐	☐	☐	☐
Awkward when you are trying to improve your appearance	☐	☐	☐	☐	☐
Nervous when you think about others seeing your appearance	☐	☐	☐	☐	☐

85. Indicate your level of agreement with the following…

	Strongly agree	Agree	Disagree	Strongly disagree
On the whole, I am satisfied with myself	☐	☐	☐	☐
At times, I think I am no good at all	☐	☐	☐	☐
I feel that I have a number of good qualities	☐	☐	☐	☐
I am able to do things as well as most other people	☐	☐	☐	☐
I feel I do not have much to be proud of	☐	☐	☐	☐
I certainly feel useless at times	☐	☐	☐	☐
I feel that I'm a person of worth, at least on an equal place with others	☐	☐	☐	☐
I wish I could have more respect for myself	☐	☐	☐	☐
All in all, I am inclined to feel that I am a failure	☐	☐	☐	☐
I take a positive attitude toward myself	☐	☐	☐	☐

86. Has a health professional ever diagnosed you with the following? How old were you when first diagnosed?

	Yes	Age first diagnosed
Asthma	☐	____ years
Migraine headaches	☐	____ years
Food allergies	☐	____ years
Other allergies	☐	____ years
Thyroid condition	☐	____ years
Mood disorder (depression, bipolar disorder)	☐	____ years
Anxiety disorder (phobia, fear of social situations, obsessive-compulsive disorder, panic disorder, generalized anxiety disorder)	☐	____ years
Learning disability (attention deficit disorder, dyslexia)	☐	____ years
Eating disorder (anorexia, bulimia)	☐	____ years
Back problems	☐	____ years
Intestinal or stomach ulcers	☐	____ years
Bowel disorder (Crohn's disease, ulcerative colitis, irritable bowel)	☐	____ years
Cholesterol or lipid problems	☐	____ years
Diabetes (type 1)	☐	____ years
Diabetes (type 2)	☐	____ years

	Yes	Age first diagnosed
High blood pressure (hypertension)	☐	____ years
Insomnia	☐	____ years
Obstructive sleep apnea	☐	____ years
Other sleep disorder	☐	____ years
Concussion	☐	____ years
Other (specify)_____	☐	____ years

87. In the past month, did you take any of the following medications, either prescription or over-the-counter?

	Yes
Pain relievers (aspirin, Tylenol, arthritis medicine, anti-inflammatories)	☐
Tranquilizers (Valium, Ativan)	☐
Diet pills (Ponderal, Fastin)	☐
Anti-depressants (Prozac, Paxil, Effexor)	☐
Codeine, Demerol or morphine	☐
Allergy medicine (Allegra, Reactine)	☐
Asthma medications (inhalers, nebulizers)	☐
Cough or cold remedies	☐
Penicillin or other antibiotics	☐
Mood stabilizers (Lithium, Epival)	☐
Major tranquilizers, anti-psychotics, neuroleptics (Risperidol, Olanzapine, Seroquel)	☐
Thyroid medication (Synthroid, Levothyroxine)	☐
Steroids	☐
Insulin	☐
Pills to control blood sugar levels	☐
Sleeping pills (Imovane, Nytol, Starnoc, melatonin)	☐
Stomach remedies	☐
Laxatives	☐
Birth control pills	☐
Blood pressure medication	☐
Cholesterol pills (Lipitor, Statins)	☐

Other (specify)_____	☐

88. Thinking about the amount of stress in your life, would you say that most days are…?

- ☐ Not at all stressful
- ☐ Not very stressful
- ☐ A bit stressful
- ☐ Quite stressful
- ☐ Extremely stressful

89. In the past two weeks, how much of the time have you…?

	At no time	Some of the time	Slightly less than half of the time	Slightly more than half of the time	Most of the time	All the time
Felt low in spirits or sad	☐	☐	☐	☐	☐	☐
Lost interest in, or could no longer enjoy your daily activities	☐	☐	☐	☐	☐	☐
Felt lacking in energy and strength	☐	☐	☐	☐	☐	☐
Felt less self-confident	☐	☐	☐	☐	☐	☐
Had a bad conscience or feelings of guilt	☐	☐	☐	☐	☐	☐
Felt that life wasn't worth living	☐	☐	☐	☐	☐	☐
Had difficulty concentrating (when reading the newspaper or watching TV)	☐	☐	☐	☐	☐	☐
Felt very restless	☐	☐	☐	☐	☐	☐
Felt subdued or slowed down	☐	☐	☐	☐	☐	☐
Had trouble sleeping at night or waking up too early	☐	☐	☐	☐	☐	☐
Suffered from reduced appetite	☐	☐	☐	☐	☐	☐
Suffered from increased appetite	☐	☐	☐	☐	☐	☐

90. Have you ever…?

	Yes
Seriously considered committing suicide (taking your own life)	☐
Attempted to commit suicide (tried taking your own life)	☐
Spoken to a health professional about your suicidal thoughts	☐

91. In the past 2 weeks, how often have you been bothered by …?

	Not at all	Several days	Over half the days	Nearly every day
Feeling nervous, anxious, or on edge	☐	☐	☐	☐
Not being able to stop or control worrying	☐	☐	☐	☐
Worrying too much about different things	☐	☐	☐	☐
Trouble relaxing	☐	☐	☐	☐
Being so restless that it's hard to sit still	☐	☐	☐	☐
Becoming easily annoyed or irritable	☐	☐	☐	☐
Feeling afraid as if something awful might happen	☐	☐	☐	☐

92. In the past month, how often did you feel…?

	Never	Rarely	Sometimes	Often	Most of the time	Always
Happy	☐	☐	☐	☐	☐	☐
Interested in life	☐	☐	☐	☐	☐	☐
Satisfied	☐	☐	☐	☐	☐	☐
You had something important to contribute to society	☐	☐	☐	☐	☐	☐
You belonged to a community (like a social group, or your neighborhood)	☐	☐	☐	☐	☐	☐
That our society is becoming a better place for people like you	☐	☐	☐	☐	☐	☐
That people are basically good	☐	☐	☐	☐	☐	☐
That the way our society works makes sense to you	☐	☐	☐	☐	☐	☐
That you liked most parts of your personality	☐	☐	☐	☐	☐	☐
Good at managing the responsibilities of your daily life	☐	☐	☐	☐	☐	☐
You had warm and trusting relationships with others	☐	☐	☐	☐	☐	☐
You had experiences that challenged you to grow and become a better person	☐	☐	☐	☐	☐	☐
Confident to think or express your own ideas and opinions	☐	☐	☐	☐	☐	☐
Your life has a sense of direction or meaning to it	☐	☐	☐	☐	☐	☐

93. In the past 12 months, how often did you…?

	Never	Less than once a month	1-3 times per month	1-6 times per week	Every day
Use electronic cigarettes without nicotine	☐	☐	☐	☐	☐
Use electronic cigarettes with nicotine	☐	☐	☐	☐	☐
Use electronic cigarettes to smoke marijuana, hash oil, liquid or wax	☐	☐	☐	☐	☐
Smoke flavored cigarettes or cigarillos	☐	☐	☐	☐	☐
Smoke cigars or a pipe, use bidis, chewing tobacco and/or snuff	☐	☐	☐	☐	☐
Smoke cigarillos	☐	☐	☐	☐	☐
Use a waterpipe (hubble bubble, nargilé, shisha)	☐	☐	☐	☐	☐
Drink energy drinks (Red Bull, Monster) without alcohol	☐	☐	☐	☐	☐
Drink energy drinks mixed with alcohol	☐	☐	☐	☐	☐
Drink alcoholic beverages (beer, wine, liquor)	☐	☐	☐	☐	☐
Drink 5 or more alcoholic beverages on one occasion	☐	☐	☐	☐	☐
Use pain relief pills (Percocet, Percodan, Demerol, OxyNeo, OxyCotin, codeine) without a prescription or without a doctor telling you to take them	☐	☐	☐	☐	☐
Use marijuana, cannabis or hashish without tobacco	☐	☐	☐	☐	☐
Use marijuana, cannabis or hashish mixed with tobacco	☐	☐	☐	☐	☐
Use cocaine	☐	☐	☐	☐	☐
Use speed (amphetamines)	☐	☐	☐	☐	☐
Use ecstasy (MDMA) or other similar drugs	☐	☐	☐	☐	☐
Use hallucinogens (PCP, LSD (acid), mushrooms)	☐	☐	☐	☐	☐
Use inhalants (glue, gasoline)	☐	☐	☐	☐	☐
Use heroin (smack, junk)	☐	☐	☐	☐	☐
Use another illicit drug	☐	☐	☐	☐	☐
Play games (cards, bingo, dice) for money	☐	☐	☐	☐	☐
Bet money (slot machines, sports pool, casino, over the Internet)	☐	☐	☐	☐	☐
Buy lottery tickets (6-49, Sports Select, Instant lottery, Scratch and win)	☐	☐	☐	☐	☐
Use a smartphone APP (Moves and Strava) that monitors your physical activity	☐	☐	☐	☐	☐
Wear a fitness device (Fitbit, Jawbone, Apple Watch) that monitors your physical activity	☐	☐	☐	☐	☐

94. In the past month, what time did you usually go to bed at night?

_____

95. In the past month, how long has it usually taken you to fall asleep at night?

_____ minutes

96. In the past month, what time did you usually get up in the morning?

_____

97. In the past month, how many hours of actual sleep did you usually get at night?

_____ hours of sleep

98. In the past month, how often did you experience each of the following?

	Never	Less than once a week	1-2 times per week	3 or more times per week
Unable to get to sleep within 30 minutes	☐	☐	☐	☐
Woke up in the middle of the night or early morning	☐	☐	☐	☐
Had to get up to use the bathroom	☐	☐	☐	☐
Could not breathe comfortably while sleeping	☐	☐	☐	☐
Coughed or snored loudly	☐	☐	☐	☐
Felt too cold while sleeping	☐	☐	☐	☐
Felt too hot while sleeping	☐	☐	☐	☐
Had bad dreams	☐	☐	☐	☐
Had pain while sleeping	☐	☐	☐	☐
Took prescribed or “over the counter” medicine to help you sleep	☐	☐	☐	☐
Had trouble staying awake while driving, eating meals, engaging in social activities	☐	☐	☐	☐

99. In the past month, has it been a problem for you to keep up enough enthusiasm to get things done?

☐ No problem at all
☐ Only a very slight problem
☐ Somewhat of a problem
☐ A very big problem

100. How long before going to bed at night do you usually…?

	Less than 30 minutes	Between 30-59 minutes	Between 1-2 hours	More than 2 hours	Not applicable
Smoke cigarettes	☐	☐	☐	☐	☐
Do physical activity	☐	☐	☐	☐	☐
Drink coffee	☐	☐	☐	☐	☐
Drink alcohol	☐	☐	☐	☐	☐
Use marijuana	☐	☐	☐	☐	☐
Use screens (TV, iPad, reading tablet, smartphone)	☐	☐	☐	☐	☐
Meditate or do yoga	☐	☐	☐	☐	☐

101. How true are each of the following for you…?

	Not at all true	A bit true	Very true
Cigarette ads are 'cool'	☐	☐	☐
Ads in magazines tell the truth	☐	☐	☐
TV ads are boring	☐	☐	☐
TV beer commercials make me want to be like the people in them	☐	☐	☐
I like to read ads in magazines	☐	☐	☐
Warnings on cigarettes packages make me afraid to smoke	☐	☐	☐
I like to watch TV ads	☐	☐	☐
Cigarette ads make me want to smoke	☐	☐	☐
Ads make us buy things we don't really need	☐	☐	☐
People who smoke are very influenced by cigarette ads	☐	☐	☐
Ads help keep people up to date about new products	☐	☐	☐
I usually want the products advertised on TV	☐	☐	☐

102. People living in Canada come from many backgrounds. Are you…?

- ☐ White (British, French, Italian, Portuguese, Ukrainian, Russian, Israeli)
- ☐ Chinese
- ☐ South Asian (East Indian, Pakistani, Bangladeshi, Sri Lankan)
- ☐ Black
- ☐ Latin American, Central American, South American (Mexican, Brazilian, Chilean, Guatemalan, Venezuelan, Colombian, Argentinian, Salvadorian, Costa Rican)
- ☐ Southeast Asian (Cambodian, Indonesian, Laotian, Vietnamese, Malaysian)
- ☐ Arabic
- ☐ West Asian (Afghan, Iranian)
- ☐ Aboriginal (First Nations, Inuit, Métis, non-status Indian)
- ☐ Japanese
- ☐ Other (specify)_____

103. How far have you gone in school?

- ☐ Attended high school, but did not graduate
- ☐ Graduated high school
- ☐ Attended CEGEP, community/technical college, but did not graduate
- ☐ Graduated CEGEP, community/technical college
- ☐ Attended university (or teacher's college), but did not graduate
- ☐ Graduated university with a Bachelor's degree
- ☐ Graduated university with a Master's degree
- ☐ Graduated university with a PhD
- ☐ Other (specify) _____

104. What is your current marital status?

- ☐ Single
- ☐ Married
- ☐ Common-law
- ☐ Divorced
- ☐ Separated
- ☐ Other (specify) _____

105. Are you currently enrolled as a full- or part-time student?

- ☐ No
- ☐ Yes, Full-time. Where?_____
- ☐ Yes, Part-time. Where?_____

106. Are you currently working at a job or business (paid or unpaid)?

- ☐ No → **Go to question 108**
- ☐ Yes

107. About how many hours per week do you usually work at your job/business (paid or unpaid)?

_____hours per week

108. What is your best estimate of the total income, before taxes and deductions, of all household members from all sources in the past 12 months?

- ☐ Less than $20 000
- ☐ 20 000$ - 29 999$
- ☐ 30 000$ - 39 999$
- ☐ 40 000$ - 49 999$
- ☐ 50 000$ - 59 999$
- ☐ 60 000$ - 69 999$
- ☐ 70 000$ - 79 999$
- ☐ 80 000$ - 99 999$
- ☐ 100 000$ - 119 999$
- ☐ 120 000$ - 149 999$
- ☐ 150 000$ or more
- ☐ Don't know

109. Please complete this chart about your residential history beginning with where you currently live and working back to where you last lived in high school (13-14 years ago).

		Number and Street	City	Number of years lived at this address (if less than 12, write LT12)
1	Current address			
2	Address prior to 1			
3	Address prior to 2			
4	Address prior to 3			
5	Address prior to 4			
6	Address prior to 5			

110. To help us locate you for the next follow-up, what is your….?

Home telephone number _____

Cell phone number _____

E-mail address _____

Comments for us:

_____

_____

_____

_____

END OF QUESTIONS
THANK YOU SO MUCH FOR RESPONDING!

APPENDIX H

Items Removed from Original RTEX items, Based on Psychometric Analyses (Study 3)

Eliminated items
Exergames are irritating to play
I think that playing exergames is a good way to integrate physical activity into my life
Exergames are calming to play
I think that I will play exergames for many years