The Injury Consequences of Promoting Physical Activity

An Evidence Review

UBC

BC INJURY research and prevention unit

CHILD & FAMILY RESEARCH INSTITUTE

Prepared by:

BC Injury Research and Prevention Unit

Alberta Girardi, Research Assistant
Dr. Shelina Babul, Associate Director
Fahra Rajabali, Researcher
Dr. Ian Pike, Director

April, 2013

Contact:
BC Injury Research and Prevention Unit
F508 – 4480 Oak Street
Vancouver, BC V6H 3V4
604.875.3776
bcinjury1@cw.bc.ca

Suggested citation:
Girardi A, Babul S, Rajabali F & Pike I. (2013). *The Injury Consequences of Promoting Physical Activity: An Evidence Review.* A report prepared by the BC Injury Research and Prevention Unit for the Provincial Health Services Authority. Vancouver, BC.

Table of Contents

Executive Summary

The purpose of this report is to summarize and synthesize recent research evidence on the injury consequences of promoting physical activity. The guiding research question was whether individuals who increase their levels of physical activity are at an increased (or decreased) risk of injury as a result. A secondary research question was whether overweight and/or obese individuals are at an increased risk of exercise-related injuries compared with individuals who are of healthy weight.

Method

Specific criteria were developed to clearly define the type of research that would be considered relevant to the review. Five electronic databases (CINAHL, EMBASE, ERIC, Medline, PsycINFO) were searched for evidence on injuries associated with physical activity promotion. The search strategy required that the title of the report contained both 1) terms related to physical activity *and* 2) terms related to promotion. The search produced 18,668 unique citations that were screened for relevance using a pre-determined set of questions. A total of 55 unique studies were identified that met the inclusion criteria. Interviews were conducted with key informants to supplement the information provided by the database search.

Results

The largest proportion of studies were conducted in the United States (40%), followed by Canada (15%) and Australia (15%). The most commonly reported purpose of the studies included increasing activity levels, reducing weight or improving body composition, and improving fitness levels. Many reports simply included a statement that the study was conducted to evaluate the feasibility or effects of the intervention. Most studies (82%) used a randomized controlled trial (RCT) research design, in which participants were randomly assigned to an exercise intervention group or to a comparison group.

The majority of physical activity promotion interventions (60%) incorporated more than one type of exercise, including aerobic or endurance training (e.g., walking, running, cycling), resistance or strength training (e.g., weight lifting, squats, pushups), stretching or flexibility exercises, and balance exercises. Other types of activities included group games, video games, dance, yoga, team sports, and active commuting to work. The frequency of the prescribed or recommended physical activity ranged from one day per week to 7 days per week, and the length of each prescribed physical activity session ranged from 10 minutes to 2 hours. Sixteen reports (29%) contained information about strategies that were used to prevent injury or ensure the safety of the participants while they were exercising.

The number of participants who completed each study ranged from n = 6 to n = 2,011; mean ages ranged from 5 years to 85 years. Eleven studies (20%) included samples of children and adolescents aged 18 years or younger, nine studies (16%) included only adults between the ages of 19 and 65 years, and twelve studies (22%) included adults over the age of 65 years. Twenty-three studies (42%) included samples of adult participants that were selected on the basis of having a specific health condition. Among the studies in which the weight of the participants was reported, one study (2%) included participants who were underweight, 49% of studies included participants who were of healthy weight, 75% of studies included

participants who were overweight, and 62% included participants who were obese. Only 5 studies (9%) included data on the number of participants with injuries at baseline.

Almost two-thirds of the reports (62%) did not clearly indicate how participants were asked to report injuries related to physical activity. In 14 studies (25%), injuries were assessed with a questionnaire, checklist or form. In two studies (4%), participants recorded injuries in diaries or logs. In two studies the individuals who supervised the exercise sessions monitored the participants for injuries. In three studies injuries were measured through the use of a trial-related monitoring system for adverse events. In two studies participants self-reported injuries, but it was not clear whether (or how) the participants were asked about injuries. In only two studies (4%) did the authors indicate whether the methods used to assess injuries were reliable or valid.

In only one of the 11 studies that included samples of children and/or adolescents were any injuries reported that occurred during the prescribed exercise sessions (Beaulac et al., 2011). In one of the few studies in which injury was a primary outcome, Collard et al. (2010) reported injury rates of 0.33 per 1,000 hours of physical activity for a sub-sample of the intervention group who engaged in high levels of physical activity. In the remaining 9 studies, the authors reported that no injuries occurred (or were reported) during the physical activities promoted as part of the intervention.

In 7 of 9 studies that included adults under the age of 65 years, one or more participants were reported to have experienced injuries. In one of the few studies in which injury was a primary outcome, Janney and Jakicic (2010) reported that 13% of participants reported lower body musculoskeletal injuries that could be attributed to any form of physical activity over an 18-month period. No significant differences were observed among four intervention groups in the frequency of injury. Participants with a higher BMI were more likely to experience injuries than those with a lower BMI.

In 5 of 12 studies that included adults over the age of 65 years, one or more participants were reported to have experienced injuries. In one of the few studies in which injury was a primary outcome, Campbell et al. (2012) reported that among participants in the intervention group, 55% of the reported injuries were attributed to sports or physical activity, whereas among participants in the control group, 30% of the reported injuries were attributed to sports or physical activity. However, this difference was not statistically significant. Another notable result is that the largest proportion of injuries in both the intervention and control groups was attributed to sports or physical activity. Body weight and BMI at baseline were not significant predictors of injury.

In 14 of 23 studies that included participants with specific health conditions, one or more participants were reported to have experienced injuries. The study by Schmitz et al. (2005) was the only one in which both the exercise intervention group and the no-exercise control group were asked to report injuries. In this study, cancer patients participated in a resistance training program. Four participants in the intervention group (11% of the group) reported back injuries, and one participant in the control group (3% of the group) reported shoulder tendonitis that was attributed to participation in the study.

Discussion

The purpose of this report was to summarize and synthesize research on the injury consequences of promoting physical activity. In half of the studies in which physical activity was promoted, none of the participants were reported to have sustained injuries. Among the studies in which one or more participants were injured, the number of participants who sustained injuries was typically small. In many studies, the proportion of participants who were injured as a result of physical activity was under 10% (typically involving only 1 or 2 participants), and most of the reported injuries were minor (e.g., muscle strain, sprains). Among many of the studies in which higher proportions (> 10%) of participants were reported to have sustained injuries, the authors reported symptoms such as pain and discomfort as injuries, the source of the injuries included any form of physical activity as opposed to activity that was required as part of the intervention, the interventions were of a longer duration, and the authors were less likely to have reported the methods by which injuries were assessed.

A major limitation of the literature generally was that few studies in which physical activity was promoted included data regarding the potential harms of participating in physical activity. Among the studies included in this review, all contained data on injuries related to physical activity, but only three studies (5%) included injury as a primary outcome variable (Campbell et al., 2012; Collard et al., 2010; Janney & Jakicic, 2010). In most studies included in this review, the authors did not provide information to clearly indicate how injuries were defined or measured, and a great degree of variability was observed across studies as to the types of injuries that were reported. It is vital that researchers clearly indicate the methods by which injuries are assessed, clearly define the types of injury that are assessed, and use reliable and valid measures.

In future studies, it would be ideal to measure injuries associated with the promoted physical activity, as well as injuries associated with other types of physical activity, and researchers should report rates of injury with respect to the total amount of exposure to physical activity. Information about injury-prevention strategies should be included in future research in which injury rates are reported, because these would be expected to impact the frequency with which the participants sustain injuries. Additional research is needed to determine whether overweight or obese individuals are at a greater risk of exercise-related injuries compared with individuals of healthy weight, and to compare rates of injury associated with different forms of physical activity.

Bearing in mind the limitations of the evidence, the results of this review suggest that increasing physical activity is unlikely to increase the risk of severe injury, and that a small proportion of individuals who increase their physical activity can be expected to experience minor injuries. Therefore, those who seek to improve their health by choosing a more active lifestyle, as well as those who promote physical activity, can rest assured that injury is not an inevitable consequence of physical activity. On the other hand, some of the participants in the reviewed studies did experience minor injuries as a result of participating in physical activity, and a few participants experienced more serious injuries, such as fractures. These observations suggest that injury prevention must play a role within individual and community-based efforts to increase physical activity.

1.0 Introduction

The purpose of this report is to summarize and synthesize recent research evidence on the injury consequences of promoting physical activity. The guiding research question was whether individuals who increase their levels of physical activity are at an increased (or decreased) risk of injury as a result. A secondary research question was whether overweight and/or obese individuals are at an increased risk of exercise-related injuries compared with individuals who are of healthy weight.

The Canadian body weight classification system provides a method for categorizing individuals into four main weight categories according to associated health risks: underweight, normal weight, overweight, and obese (Health Canada, 2003). Classification is based on body mass index (BMI), which is calculated by dividing an individual's weight in kilograms by his/her squared height in metres (BMI = kg/m^2). The classification system for adults is provided in Figure 1. Children under the age of 19 years are classified using a different system due to variability in weight by age and sex. According to the U.S. Centers for Disease Control (CDC), children are classified as overweight if their weight is above the 85^{th} percentile and as obese if their weight is above the 95^{th} percentile (Ogden & Flegal, 2010).

Figure 1. BMI categories and associated health risk. Reproduced from Health Canada (2003).

BMI	Weight Category	Health Risk
< 18.5	Underweight	Increased risk
18.5 – 24.9	Normal weight	Least risk
25.0 – 29.9	Overweight	Increased risk
30 and over	Obese	
30.0 – 34.9	Obese Class I	High risk
35.0 – 39.9	Obese Class II	Very high risk
> 40.0	Obese Class III	Extremely high risk

The results of the Canadian Health Measures Survey indicated that approximately 21% of females and 19% of males between the ages of 20 and 39 years were obese; 23% of females and 37% of males in this age category were overweight. A higher prevalence of overweight and obesity was observed in adults between the ages of 40 and 69 years (Shields et al., 2010). Among children and adolescents aged 5 to 17 years, 19.8% were overweight and 11.7% were obese (Roberts et al., 2012). Health problems known to be associated with obesity include diabetes, some types of cancer, hypertension, osteoarthritis, cardiovascular disease, and psychosocial difficulties (Health Canada, 2003).

Physical activity is one of the recommended strategies for weight loss and the prevention of weight gain (Health Canada, 2006), as well as the prevention of chronic health conditions (Warburton et al., 2010). Previous research indicates that increasing physical activity may be an effective strategy for promoting healthy weight in a variety of populations, especially when combined with dietary restriction; although, study results are inconsistent and the effects of exercise on weight loss are limited (Brown & Summerbell, 2009; Curioni & Lourenco, 2005; Egberts et al., 2012; Stehr & von Lengerke, 2012).

The Canadian Physical Activity Guidelines recommend that children and youth aged 5 to 17 years engage in at least 60 minutes of moderate to vigorous physical activity every day, and that adults engage in at least 150 minutes of moderate to vigorous physical activity each week (Canadian Society for Exercise Physiology, 2012). However, the results of the Canadian Health Measures Survey indicated that only 15% of adults, and less than 10% of children and youth, are currently meeting these guidelines (Colley et al., 2011a; Colley et al., 2011b).

Clearly, there is a need for increased public health efforts to ensure that British Columbians are meeting the recommended physical activity guidelines. However, there are concerns that increasing physical activity levels can lead to an increase in injuries. The results of cross-sectional studies suggested that those who engaged in higher levels of physical activity were more likely to sustain injuries (Clark et al., 2008; Field et al., 2011; Hootman et al., 2001; Warsh et al., 2010). Results of other studies suggested that overweight and obese individuals may be at a higher risk of sustaining exercise-related injuries than those who are of healthy weight (Gomez et al., 1998; McHugh, 2010; Rose et al., 2008). This is of particular concern given that physical activity is promoted as a weight loss strategy.

2.0 Method

Specific criteria were developed to clearly define the type of research that would be considered relevant to the review (Appendix A). Five electronic databases (CINAHL, EMBASE, ERIC, Medline, PsycINFO) were searched for evidence on injuries associated with physical activity promotion. The search strategy required that the title of the report contained both 1) terms related to physical activity (e.g., activity, sport, exercise) *and* 2) terms related to promotion (e.g., intervention, prescription, program). The complete search strategy is provided in Appendix B.

The title search produced 19,415 citations that were subsequently uploaded into the reference management software, Endnote, at which time unique reference identification numbers were assigned to each citation. After duplicate citations were removed, 18,668 unique citations remained.

The 18,668 unique citations were uploaded to the online systematic review software (DistillerSR) where they were screened for relevance. First, the titles of the citations were screened in order to quickly exclude articles that were clearly irrelevant (i.e., they did not describe an intervention to promote physical activity, or they included participants in one of the excluded groups). After the title screen, 5,474 articles advanced to the following stage of the screening process. In the second stage of the screening process, the abstracts of each article were reviewed and 3,020 advanced to the final stage of the screening process. In the final screening stage, the electronic full-text of each document was downloaded in PDF format. Each article was

searched for one or more of 5 injury key words using the "find" function of the PDF reader. Among studies that contained one or more injury key words, relevant sections of the article were reviewed in order to determine whether the study included the assessment of injuries related to physical activity.

A total of 60 studies were identified that met the inclusion criteria. It was determined that 5 articles included samples of participants that were the same as one of the other relevant articles. In other words, two separate journal articles had been published with data from the same individuals. Therefore, the evidence contained in this review is based on 55 unique samples of participants.

Interviews were conducted with key informants to supplement the information provided by the database search. Interview questions are provided in Appendix C.

3.0 Results

Data from 55 unique studies were extracted from the reports and summarized in a series of evidence tables. A detailed explanation of the evidence tables, including definitions of all variables, is provided in Appendix D. Separate tables were created for four groups of studies based on the population of interest: those that included samples of children and adolescents aged 18 years and under (Appendix E), those that included samples of adults between the ages of 19 and 65 years (Appendix F), those that included samples of adults including adults over the age of 65 years (Appendix G), and those that included samples of adult participants with specific health conditions including cancer, diabetes, osteoarthritis, and heart failure (Appendix H). The results are reported for each group separately. First, the characteristics of the studies are described in order to provide a context for the results. In the following section, key characteristics of the studies are highlighted including the proportions of studies that included data on the variables of interest; however, note that all available information about these characteristics is provided in the evidence tables in the appendices. The characteristics of the 55 studies are described together, but obvious differences among the four population groups are highlighted.

3.1 General study characteristics

Eleven studies (20%) included samples of children and adolescents aged 18 years or younger, nine studies (16%) included only adults between the ages of 19 and 65 years, and twelve studies (22%) included adults over the age of 65 years. Among the studies that included adults over the age of 65 years, half also included adults under the age of 65 years. Twenty-three studies (42%) included samples of adult participants that were selected on the basis of having a specific health condition, including cancer (16%), diabetes (15%), osteoarthritis (2%), heart failure (2%), schizophrenia (4%), and those with one or more diseases or risk factors (4%).

The largest proportion of studies were conducted in the United States (40%), followed by Canada (15%) and Australia (15%), the Netherlands (5%), France (4%), New Zealand (4%), Sweden (4%), and the United Kingdom (4%). One study (2%) was conducted in each of the following countries: Denmark, Germany, Italy, Norway, Switzerland, and Taiwan. One clear pattern emerged among the different population groups. All

the studies that included cancer patients were conducted in North America; 7 in the United States and 2 in Canada.

Almost half of the studies (47%) were identified by name, such as the Sedentary Women Exercise Adherence Trial (SWEAT; Baker et al., 2007) and the Stanford Sports to Prevent Obesity Randomized Trial (SPORT; Weintraub et al., 2008). No two studies described the same physical activity intervention. In other words, each of the 55 reports described a different method of promoting physical activity.

All reports contained a statement of the purpose of the study. The most commonly reported purpose of the studies included increasing activity levels, reducing weight or improving body composition, and improving fitness levels. Many reports simply included a statement that the study was conducted to evaluate the feasibility or effects of the intervention. Some of the studies that included participants with health conditions evaluated the effects of the physical activity intervention on outcomes specific to the health condition, such as cancer fatigue (Dodd et al., 2010) or glycemic control (Wisse et al., 2010).

The majority of the studies (82%) used a randomized controlled trial (RCT) research design, in which participants were randomly assigned to an exercise intervention group or to a comparison group. Of these 45 studies, 24 included a no-exercise control group in which the participants were not exposed to an intervention to promote physical activity, 21 included a comparison group in which participants were exposed to a physical activity intervention that was different from that of the main intervention group (typically a less specific or rigorous exercise prescription), and 4 included both a no-exercise comparison group and a physical activity comparison group. Two studies used a quasi-experimental design in which the participants were not randomly assigned to intervention and comparison groups. Nine studies used a pre-post design in which a single group of participants was assessed before and after the intervention. One qualitative study included an assessment of participants' subjective experiences of participating in the physical activity intervention. The studies that included samples of children and adolescents or adults with special health conditions were somewhat less likely to have used RCT designs than studies that included samples of adults and/or older adults.

3.2 Intervention Characteristics

The majority of physical activity promotion interventions (60%) incorporated more than one type of exercise, including aerobic or endurance training (e.g., walking, running, cycling), resistance or strength training (e.g., weight lifting, squats, pushups), stretching or flexibility exercises, and balance exercises. Overall, 65% of interventions included aerobic training, 51% included resistance training, 35% included stretching, and 11% included balance exercises. Other types of activities, such as group games, video games, dance, yoga, team sports (e.g., soccer, football), and active commuting to work were included in 35% of the interventions. Five reports (9%) did not specify the type of exercise that was prescribed to participants. Samples with child and adolescent participants were less likely to include aerobic exercises and more likely to include other activities (e.g., games, dance,) compared with the other groups. Balance exercises were included only in interventions for adults over the age of 65 years.

The frequency of the prescribed or recommended physical activity ranged from one day per week to 7 days per week. Approximately one-quarter (24%) of the interventions were 1-2 days per week, 47% were 3-5 days per week, and 11% were 6-7 days per week. Four interventions (7%) included a recommendation to exercise 3-4 *or more* days per week, or most days of the week. Six reports (11%) did not include information about the frequency of recommended exercise. Interventions for those with special health conditions and children/adolescents typically took place 2-5 days per week, and interventions for adults (including older adults) typically took place 3-7 days per week.

The length of each prescribed physical activity session ranged from 10 minutes to 2 hours. The largest proportion of interventions (40%) involved exercise sessions of 40-60 minutes, 22% were 30 minutes or less, 15% were more than 60 minutes, and 24% of the reports did not specify the length of the recommended exercise sessions. Interventions for all groups of adults typically involved exercise sessions of 30-60 minutes, whereas interventions for children and adolescents typically involved exercise sessions of 60-90 minutes. Combining the data on the frequency and length of prescribed physical activity, participants were asked to engage in the prescribed physical activity for between 20 and 420 minutes per week; most interventions involved two or more hours per week of activity.

Approximately two-thirds (64%) of the reports specified the intensity of the prescribed physical activity. Many of the reports simply described the exercise intensity as low, moderate, or high. Among these studies, all but one of the interventions included moderate-intensity physical activity, and some also incorporated low and/or high intensity activities. One study included only high-intensity exercise. The other reports described the target exercise intensity on the Borg Scale of Perceived Exertion, or specified a percentage of participants' maximal heart rate. Interventions for children and adolescents were least likely to specify a target intensity compared with the other population groups, and interventions for participants with specific health conditions were most likely to specify a target intensity.

The majority of the interventions (55%) included a home-based component, meaning that the participants were asked to participate in the physical activity program on their own and were not required to travel to a specific location to exercise. Some of the exercise interventions (40%) included a centre-based component, meaning that the participants were required travel to a specific location, such as a fitness centre or community centre, to engage in the exercise program. A smaller proportion (20%) of the interventions took place at another location, including schools and outdoor settings such as parks or beaches. Twelve exercise interventions (22%) took place at two or more settings, and five reports (9%) did not contain any information about the setting of the exercise program. Interventions with child and adolescent participants were most likely to take place in school settings.

Most studies (85%) included basic information about the individuals who prescribed and/or supervised the PA interventions, and the remaining 15% of studies contained no information about exercise instructors. Instructors were most frequently described as exercise trainers, physiologists, or specialists. Other instructors included physiotherapists, nurses, dieticians, physicians, and teachers.

The duration of the physical activity promotion programs varied widely from 5 weeks to two years. One-quarter of the interventions took place over a period of 3 months or less, 40% took place over a period of 3 months to 1 year, and 35% of the interventions took place over a period of 1 year or more.

Most interventions (73%) included components in addition to a simple physical activity prescription. Examples of such components include motivational counseling, instruction on exercise techniques, exercise-related supplies (e.g., exercise equipment, video games, pedometers, bicycles), educational workshops or written materials (e.g., handbooks, newsletters, manuals), gym memberships, dietary supplements, and nutrition recommendations. Given the wide variety of these additional components, and combinations thereof, it was beyond the scope of this review to provide specific proportions of interventions with each type and combination of components.

One intervention component was of particular interest in the current review: injury prevention strategies. Sixteen reports (29%) contained information about strategies that were used to prevent injury or ensure the safety of the participants while they were exercising. Interventions for adults aged 19-65 years were least likely to incorporate injury-prevention strategies, and interventions for cancer patients were most likely to incorporate injury-prevention strategies. Some reports indicated that activities such as warm-up and cool-down sessions were included as part of the intervention, but these are only described here if the authors specifically stated that these activities were included to ensure participant safety or prevent injury.

Of the 11 interventions for children/adolescents, 4 included injury-prevention strategies. Collard et al. (2010) provided a website and monthly newsletters for children and parents, as well as classroom posters, aimed at improving knowledge about injury prevention. Nasca et al. (2010) reported that coaches provided instruction on basic techniques associated with the track-and-field activities that comprised the intervention, before the actual intervention began, in order to minimize the risk of injury. In the study by Cowen et al. (2009) physical education teachers received training on how to safely provide a strength training program for children and adhered to recommendations of the American College of Sports Medicine and the American Academy of Pediatrics. Furthermore, the authors noted that the strength training program followed a safety protocol. Finally, Weintraub et al. (2008) provided shin guards to children participating in their soccer program.

Of the 9 interventions for adults aged 19-65 years, only one included safety or injury-prevention strategies. Hemmingsson et al. (2009) reported that the content of physician counseling sessions included preventing injuries, and participants were given bicycle helmets.

Of the 12 studies that included adults over the age of 65 years, 4 included information on safety or injury prevention strategies. Bonnefoy et al. (2012) noted that the home helpers who implemented the intervention received training to help participants minimize the risk of falling during exercise. Campbell et al. (2012) reported that injury prevention strategies were incorporated in the intervention, including gradually increasing the amount physical activity over the course of the intervention, providing supervision by exercise trainers at the beginning of the intervention, and giving each participant $50 toward the purchase of athletic shoes. Bennett et al. (2008) noted that the initial telephone counseling session included safety guidelines,

including warm-up and cool-down. Finally, Cox et al. (2008) provided participants with information sheets about safety.

Of the 23 studies including participants with specific health conditions, 7 included information on safety or injury prevention strategies. Balducci et al. (2010) indicated that a specific strategy was implemented to improve the safety of the exercise intervention for patients with diabetes, which included selecting diabetologists and exercise specialists to prescribe and supervise exercise sessions. Goodrich et al. (2007) indicated that participants were instructed to gradually increase the amount of walking to reduce the risk of injury and that dieticians provided instructions on warming up and stretching. The remaining interventions incorporating safety or injury prevention strategies were conducted with cancer patients. Anderson et al. (2012) noted that the physical activity program was developed to ensure safety by encouraging a slow progression, and by including slow and controlled strength training exercises. Others reported that training programs were adjusted to the individual needs of the participants, and/or that supervision was provided at the beginning of the intervention so that participants could learn to safely perform the exercises (Rajotte et al., 2012; Schmitz et al., 2008; Winters-Stone et al., 2011). Finally, Irwin et al. (2008) provided worksheets which included topics related to injury prevention.

3.3 Participant Characteristics

The majority of the studies (93%) included details regarding inclusion or exclusion criteria (i.e., characteristics of participants that deemed them eligible or ineligible to participate in the study). Across all population groups, the most common inclusion criteria related to the participants' age and activity level. Other inclusion criteria included weight, gender, ethnicity, socioeconomic status, language, and other factors specific to the target intervention (e.g., video game use). Weight and/or body composition were more commonly used as inclusion criteria among studies that included adults between the ages of 19 and 65 years compared with the other groups. Only studies that included adults over the age of 65 years used inclusion criteria related to functional ability or mobility, living independently in the community, cognitive functioning, and fall history. The most common exclusion criteria related to medical history. Some reported the specific medical conditions that were excluded (e.g., cardiovascular disease, previous injury), whereas others stated simply that participants were excluded if they had medical conditions that might interfere with exercise or testing (e.g., Lubans et al., 2010).

Considerable variability was observed in sample sizes. The number of participants who completed each study ranged from n = 6 to n = 2,011. Slightly more than half of the studies (56%) had samples sizes of less than 100, 36% of the studies had sample sizes between 100 and 500, and 7% had sample sizes of greater than 500.

The mean age of the participants was reported in all but one of the studies, and 56% of the reports included the age range of the participants. Mean ages ranged from 5 years to 85 years. Among studies that included children/adolescents, mean ages ranged from 5 years to 15 years. Among studies that included only adults under the age of 65 years, mean ages ranged from 26 to 58 years. Among studies that included adults over

the age of 65 years, mean ages ranged from 55 to 85 years. Finally, among studies that included participants with specific health conditions, mean ages ranged from 30 to 68 years.

The majority of the studies (95%) included information regarding the sex distribution of the participants. Two of the three studies that did not include this information were conducted with samples of children, and one was conducted with participants with diabetes. Twenty-two percent of the studies included females only, 16% of studies included males only, and 56% included both males and females. In most studies that included both males and females, there was a larger proportion of females than males, particularly in samples with adults and older adults. Samples of cancer patients were most likely to include only female participants, and samples with adults over the age of 65 years were most likely to include both males and females.

Fewer than half of the studies (44%) included information about the socioeconomic status of the participants, and approximately half of the studies (51%) included information about ethnicity. Most of the studies that reported ethnicity data included participants in two or more ethnic groups. Two studies included only Caucasian participants (Campbell et al., 2007; Kukuljan et al., 2009), two studies included only African American participants (Hooker et al., 2011; Robinson et al., 2010), and one study included only Pakistani participants (Andersen et al., 2012).

The pre-intervention (baseline) physical activity levels of the participants were reported in 80% of the studies. Studies with child/adolescent participants were least likely to include data on baseline activity compared with the other population groups. The two studies with participants with schizophrenia did not report baseline activity levels. Considerable variability was observed in the methods that were used to assess physical activity including minutes per day or per week, pedometer steps per day, days per week on which participants exercised, accelerometer counts per minute, calories expended per day, and scores on various questionnaires. Because of this variability, it was not feasible to synthesize all of the data on baseline activity levels; however, the inclusion criteria for many of the studies specified that the participants were "sedentary" or did not meet current physical activity recommendations.

Most studies (82%) included data on the baseline weight or body composition of the participants. The mean BMI of the participants was reported in 75% of the studies; the mean BMI ranged from 16 to 38. Studies that included adults between the ages of 19 and 65 years were most likely to include the mean BMI of the participants, and studies that included adults over the age of 65 years were least likely to include the mean BMI. Just over half of the studies included the mean weight of the participants; the mean weight ranged from 37 kilograms to 104 kilograms. Only 22% of the reports included data regarding the proportion of participants in one or more weight categories (i.e., underweight, healthy weight, overweight, or obese); however, using the descriptive statistics provided regarding the BMI of the participants (i.e., mean, standard deviation), it was possible to determine whether some of the other studies included participants in each weight category. Of the studies that included weight data, one study (2%) included participants who were underweight, 49% of studies included participants who were of healthy weight, 75% of studies included participants who were overweight, and 62% included participants who were obese.

Only 5 studies (9%) included data on the number of participants with injuries at baseline. Three of these studies were conducted with adults over the age of 65 years. Clemson et al. (2012) reported the percentage of participants who had been injured by falling in the past year, and Kerse et al. (2005) included the percentage of participants who reported injuries in the previous month. Campbell et al. (2012) provided detailed data regarding the percentage of participants who reported injuries to specific body parts within the previous 12 months. Wisse et al. (2010) reported the proportion of participants with diabetes who had injuries related to physical activity. Fitzgerald et al. (2011) reported the proportion of participants with osteoarthritis who had a history of knee injury and hip fracture. Three other studies excluded participants who had severe injuries (Andersen et al., 2012), injuries that would interfere with training (Lubans et al., 2011), or those who were predisposed to exercise related injuries (Janney & Jakicic, 2010).

Most studies (91%) included data on the baseline health of the participants, other than those related to weight and injury. Health variables included chronic illnesses, hospitalizations, smoking, blood pressure, heart rate, cholesterol, medications, strength and fitness, nutrition, physical function (e.g., walking speed), and mental health (e.g., depression, anxiety). The number and type of health-related factors varied widely across studies. The studies that included participants with specific health conditions included health data that were specific to the condition, such as cancer stage, type of treatment, insulin and glucose levels, and antipsychotic medications. Studies that included child and adolescent participants were least likely to include data on the health of the participants at baseline.

3.4 Evaluation Strategies

The majority of the studies (93%) included information about the strategy that was used to recruit participants into the study, but 4 studies contained no information about the recruitment strategy. Samples of children and adolescents were typically recruited through schools, although some participants were also recruited through community centres, physicians or medical clinics, and other locations (e.g., churches, shopping malls, summer camp). Among the other population groups, participants were most likely to be recruited through medical practices, local media (including newspapers), and/or through flyers or mailings. Some older adults were recruited through retirement villages or leisure care centres, and some participants with specific health conditions were recruited through registries or organizations specific to those health conditions. None of the studies included a random sample of participants from the population.

Assessment strategies in most studies (80%) included a combination of participant self-report and objective measurements (e.g., measuring weight using a scale, measuring physical activity with a pedometer). Three studies (5%) included only participant self-report data, and four studies (7%) included only objective measurements. Other assessment strategies that were used in addition to, or instead of, self-reports and measurements included parent-reports, medical record reviews, and reports by physicians or nurses.

Most studies (82%) included information about the methods that were used to assess participants' physical activity levels. Studies that included children and/or adolescents were the least likely to include information about physical activity measurement. Activity levels of children/adolescents were most likely to be assessed using accelerometers or questionnaires. Studies that included all populations of adults were most likely to

use questionnaires or exercise diaries/logs to assess physical activity. Other types of assessment included pedometers, accelerometers, bicycle trip metres, and energy expenditure using heart rate monitors or exercise machines. Activity levels in studies with older adults were measured exclusively with questionnaires or diaries/logs. Several studies included more than one physical activity measure. For example, Anderson et al. (2012) assessed baseline levels of physical activity using a questionnaire, and exercise logs to record actual physical activity during the intervention. Only 22% of the reports included information about whether the physical activity measures were reliable and/or valid.

Almost two-thirds of the reports (62%) did not clearly indicate how participants were asked to report injuries related to physical activity. Four of these reports included a statement that injuries were measured, but did not specify how. For example, Cox et al. (2008) indicated that injuries were recorded, but did not specify how they were recorded or who recorded them. In 14 studies (25%), participants were asked specific questions about injuries by completing a questionnaire, checklist or form. In two studies (4%), participants recorded injuries in diaries or logs. In two studies the individuals who supervised the exercise sessions monitored the participants for injuries. In three studies injuries were measured through the use of a trial-related monitoring system for adverse events. In two studies participants self-reported injuries, but it was not clear whether (or how) the participants were asked about injuries.

Among the 14 studies in which injuries were measured through the use of questionnaires, forms, or checklists, considerable variability was observed in the specific methods that were used to ask participants about their injuries, and the types of injuries that were recorded. For example, in the study by Collard et al. (2010), physical education teachers asked children whether they were injured while participating in physical activity within the previous week. In the study by Wilson et al. (2006), participants completed a checklist of specific symptoms that could be attributed to the exercise training program. In another study, participants responded “yes” or “no” to questions about whether they had any injuries during the exercise program (Rajotte et al., 2012). In two studies, the authors simply stated that participants answered questions, but did not report the content of those questions (Balducci et al., 2010; Kinmonth et al., 2008). In only two studies (4%) did the authors indicate whether the methods used to assess injuries were reliable or valid.

In many cases it was not possible to determine whether all participants were specifically asked to report or record any injuries or whether the injuries described in the report were spontaneously reported by participants. For example, Norton et al. (2011) reported that injuries were recorded by participants in diaries; however, it is not clear whether participants were instructed to record all injuries in their diaries, or whether some participants chose to record injuries in their diaries.

3.5 Outcomes

All included studies contained data on injuries related to physical activity, but only three studies (5%) included injury as a primary outcome variable (Campbell et al., 2012; Collard et al., 2010; Janney & Jakicic, 2010). The majority of studies (84%) assessed the effects of the intervention on two or more outcome variables, in addition to providing data on injuries. Most studies (85%) included outcomes related to the participants’ physical health; these outcomes varied widely and included blood pressure, strength and

fitness, and physical function (e.g., walking speed). Thirty-two studies (58%) included weight as one of the outcome variables, and 58% included physical activity levels as an outcome variable. Other outcome variables included mental health (38%), satisfaction with the physical activity program (24%), knowledge or attitudes about physical activity (20%), and diet or nutrition (15%). Two studies (4%) included open-ended questions to assess participants' subjective experiences of the physical activity program. Nine studies (16%) included various other outcomes such as media use, hospitalizations, costs of the program, school performance, worry about diabetes risk, and the use of cars and public transit for commuting to work.

Data on the actual physical activity levels of the participants during the intervention, or at the end of the intervention, was reported in 42% of the studies. The type of data that was reported included energy expenditure, accelerometer counts per minute, time per day/week of physical activity of varying type and intensity, number of steps per day, calories expended per day, number of days per week on which participants exercised, scores on physical activity questionnaires, and the proportion of participants who met various physical activity goals, such as 10,000 steps per day, 150 minutes per week of physical activity, or regular active commuting.

In 51% of the studies, the authors reported whether or not the physical activity levels of the participants increased significantly during, or after, the intervention. Studies that included adult participants between the ages of 19 and 65 years were most likely to include results as to whether participants increased their physical activity levels. In 6 studies, a significant increase in physical activity levels was observed in the physical activity intervention group, the increase in physical activity levels was greater in the intervention group than the control group, or the results indicated that there was a significant difference in physical activity levels between the physical activity group and the control group at the end of the intervention. In 6 studies, there was no significant change in physical activity levels over time, or no significant difference between intervention and control groups after the intervention. Among studies in which two different physical activity interventions were compared, 4 studies reported increases in physical activity levels for both groups, 3 studies reported a significantly greater increase in physical activity levels for only the target intervention, and in 3 studies the authors did not report whether changes/differences in physical activity levels were statistically significant. In three studies, the authors reported only that there was not a significant change in the physical activity levels of the control group. In the final three studies, the results varied based on the type of physical activity that was assessed.

3.5.1 Injury Outcomes – Child and Adolescent Samples

In only one of the 11 studies that included samples of children and/or adolescents were any injuries reported that occurred during the prescribed exercise sessions. Beaulac et al. (2011) reported that two of the 34 participants were injured during the weekly hip-hop dance classes over a 3-month period. The authors did not indicate the nature of the injuries or how the injuries were measured or reported, but noted that the two participants did not discontinue participation in the study as a result of the injuries. The rate of

adherence to the intervention was an average of 7.6 of a possible 13 classes. The authors did not report whether this intervention included any injury-prevention components.

The study by Collard et al. (2010) was one of the few studies in this review in which injury was assessed as a primary outcome. The authors did not report whether injuries occurred during the prescribed 5-minute physical activity sessions, but instead reported injuries related to 4 indices of physical activity: leisure time injuries, sports club injuries, physical education injuries, and total physical activity injuries. The 8-month intervention included education for students, teachers, and parents on injury-prevention strategies, in addition to exercises aimed at improving strength, speed, flexibility and coordination. Participants were divided into high-active and low-active groups according to whether their levels of physical activity were above or below the median of 414 minutes per week. Physical education teachers asked children to report activity-related injuries on a weekly basis. Injuries were recorded only if they interfered with physical activity, prevented attendance at school, or required medical attention. Total activity-related injury rates were 0.33 per 1,000 hours for the high-active intervention group and 0.37 per 1,000 hours for the low-active intervention group. The only statistically significant difference observed in injury rates between intervention and control groups was for the low-active group: participants who received the intervention had significantly fewer sports club injuries compared with the control group. There were no significant differences between intervention and control groups in rates of injury for the other activity-related injuries, or for the high-active group. However, participants who received the intervention reported fewer severe injuries than the control group.

In the remaining 9 studies, the authors reported that no injuries occurred (or were reported) during the physical activities promoted as part of the intervention. The prescribed physical activities included active video games (Maddison et al., 2011), soccer (Weintraub et al., 2008), dance (Robinson et al., 2010), track and field events (Nasca et al., 2010), playful activities for preschoolers (Puder et al., 2011), and strength training (Cowan & Foster, 2009; Faigenbaum et al., 2007; Lubans et al., 2011; Lubans et al., 2010). The duration of these interventions ranged from 5 weeks to 2 years. Only 3 of these 9 studies included information to suggest that injury prevention strategies were imparted to the participants (Cowan & Foster, 2009; Nasca et al., 2010; Weintraub et al., 2008). Among the six studies that reported adherence to the intervention, the mean rate of attendance at the prescribed exercise ranged from 20% to 95% across studies. Information about the specific methods used to assess injuries was reported in only one study; Lubans et al. (2010) reported that research assistants and instructors were asked to record injuries. In two other studies, the authors reported that injuries were systematically or formally assessed, but did not specify how injuries were assessed (Robinson et al., 2010; Weintraub et al., 2008).

No study-related injuries were reported in the two studies that included only overweight or obese participants. The remaining studies included participants who were of healthy weight in addition to those who were overweight and/or obese, or did not include any data on the participants' weight. In the two studies in which injuries were reported, the authors did not include a comparison of injuries among participants of different weights.

3.5.2 Injury Outcomes - Adult Samples

In 7 of 9 studies that included adults under the age of 65 years, one or more participants were reported to have experienced injuries. Five studies involved a comparison of one or more exercise interventions to a no-exercise control group (Andersen et al., 2012; Krustrup et al., 2009; Messier et al., 2010; Norton et al., 2011; Ross et al., 2012;) one study involved a comparison of four interventions in which physical activity was promoted but did not include a no-exercise control group (Janney & Jakicic, 2010), and one was a pre-post study in which one group of participants was assessed before and after the intervention (Hooker et al., 2011). In the remaining 2 studies, no intervention-related injuries were reported (Campbell et al., 2007; Hemmingsson et al., 2009).

The study by Janney and Jakicic (2010) was one of the few studies in this review that included injury as a primary outcome. The authors compared the effects of four different unsupervised interventions to promote physical activity among overweight and obese participants. Three groups of participants were encouraged to walk for 300, 200, and 150 minutes per week, respectively. The fourth group of participants was given printed materials related to exercise, but no specific exercise prescription; this group was identified as the control group. The authors did not report whether the intervention included injury-prevention strategies. Injuries were assessed by asking participants to respond to questions about whether they had any injuries that interfered with their ability to exercise, and whether the injuries could be attributed to physical activity, including activities of daily living. Over the 18-month intervention, 13% reported lower body musculoskeletal injuries, 4% reported back pain/injury, and 1% reported upper body musculoskeletal injuries that could be attributed to physical activity. No significant differences were observed between the intervention and control groups in the frequency of these injuries. A non-significant trend suggested that participants in the exercise group experienced injuries earlier than the control group. It is important to note that the reported injuries may or may not have been a result of participating in the prescribed physical activity.

Ross et al. (2012) assessed the effects of individually tailored unsupervised exercise counseling for overweight and obese participants. Participants in the intervention group (n = 249) were counseled to engage in 45-60 minutes of physical activity on a daily basis, but the type of physical activity promoted was not reported. The authors did not report whether injury prevention strategies were incorporated into the intervention. The control group (n = 241) received usual care from their physicians. Participants in both groups self-reported injuries, but the authors did not indicate the methods by which participants were asked to report their injuries. Over a 2-year period, the number of musculoskeletal injuries that occurred during or after exercise was 300 in the intervention group and 311 in the control group. The intervention group reported 5 exercise-related injuries requiring hospitalization and the control group reported 12 exercise-related injuries requiring hospitalization. The authors did not report whether or not these differences were statistically significant; however they reported that the physical activity levels of the intervention and control groups were not significantly different at the end of the study.

In five studies, at least one participant in the intervention group experienced injuries during the prescribed exercise sessions or during exercise testing (Andersen et al., 2012; Hooker et al., 2011; Krustrup et al., 2009;

Messier et al., 2010; Norton et al., 2011). None of these reports included information about injury-prevention strategies, and only one included information about the methods used to assess injuries (Norton et al., 2010).

Andersen et al. (2012) reported that 2 participants (3% of the intervention group) were injured at the first supervised exercise session, but did not report injuries in the control group. The 5-month intervention involved a warm-up, football or floor ball games, and strength exercises; the mean rate of attendance was 60%. Hooker et al. (2011) reported that one participant (4% of the sample) strained a leg muscle while walking during the 8-week intervention, and that none of the other participants reported adverse events; the mean rate of attendance was 85%. In three other studies, the authors reported only the proportion of participants who dropped out of the study due to injuries that occurred during intervention-related activity. One was a 6-month supervised resistance training program for overweight/obese participants, and 3 participants (6% of the intervention group) dropped out due to a minor injury associated with training; no information was provided about injuries in the control group (Messier et al., 2010). The second involved a comparison of an intervention involving varied activities (e.g., yoga, boxing, team sports), a walking intervention, and a no-exercise control group over a period of 6 weeks (Norton et al., 2011). The authors reported that there were 13 musculoskeletal injuries among participants in the two physical activity interventions that resulted in withdrawal from the study during a total of 15,300 hours of intervention, and that there was no significant difference in the number of injuries between the two physical activity intervention groups; no information was provided about injuries in the control group. The third study involved a comparison of a soccer intervention, a running intervention, and a no-exercise control group over a period of 3 months (Krustrup et al., 2009). One participant in the soccer group (8% of the group) dropped out due to an ankle sprain, 2 participants in the running group (17% of the group) dropped out (1 due to shin splints, 1 due to achilles tendinopathy), and one participant in the control group (9% of the group) dropped out due to a hamstring strain.

In the remaining two studies, no intervention-related injuries were reported. Hemmingsson et al. (2009) reported that they did not observe any 'serious' bicycle-related injuries over an 18-month period among participants who were encouraged to commute to work on their bicycles. The intervention included physician counseling on injury prevention, and bicycle helmets were provided to the participants. However, no information was provided about how injuries were measured, and the results indicated that only 29% of the participants in the intervention group cycled to work at least once per week. According to Campbell et al. (2007) no intervention-related injuries were reported among those who participated in a 12-week supervised intervention involving aerobic exercise on stationary bicycles. The authors did not provide information about injury prevention components to the intervention or the methods used to assess injuries. However, they did note that participants attended an average of 91% of the prescribed exercise sessions.

Among the 9 studies that included adult participants, 3 included only participants who were overweight or obese, 5 studies included participants who were of healthy weight in addition to those who were overweight and/or obese, and one study did not include any data on the participants' weight. None of the studies included comparisons of rates of injury between participants who were overweight/obese and participants who were of healthy weight. Because of the inconsistencies in the way in which injuries were

measured and reported, no comparisons can be made across studies to determine whether overweight or obese participants were more likely to sustain injuries compared with healthy weight participants as a result of participating in physical activity. However, Janney and Jakicic (2010) assessed the effect of BMI on injuries among a sample of overweight and obese participants. Results indicated that participants with a higher BMI were at an increased risk of injury, and experienced injuries earlier, compared to those with a lower BMI.

3.5.3 Injury Outcomes – Older Adult Samples

In 5 of 12 studies that included adults over the age of 65 years, one or more participants were reported to have experienced injuries. Three studies involved a comparison of one or more exercise interventions to a no-exercise control group (Campbell et al., 2012; King et al., 2007; Kukuljan et al., 2009). Two studies involved a comparison of two or more interventions in which physical activity was promoted, but did not include a no-exercise control group (Clemson et al., 2012; Cox et al., 2008). In the remaining 7 studies, the authors stated that no injuries occurred (or were reported) during the physical activities promoted as part of the intervention.

The study by Campbell et al. (2012) was one of the few studies included in this review in which injury was one of the primary outcome variables. Over a period of 12 months, participants engaged in 60 minutes of supervised aerobic activities on various exercise machines at an exercise facility 3 days per week, and also participated in unsupervised home-based activities such as walking and cycling 3 days per week. The participants in the control group were asked not to change their exercise habits. The authors reported that injury prevention strategies included a gradual increase in the level of prescribed physical activity, supervision by an exercise trainer, and $50 for each participant to purchase athletic shoes. The proportion of participants who adhered to at least 80% of the prescribed exercise was 71%. Participants completed a questionnaire in which they reported whether they had injuries that interfered with their ability to engage in their daily activities in the previous 12 months. They were asked to identify whether their injuries were attributed to their occupation, leisure activities, home maintenance/repair, or sports/physical activity. There was no significant difference between the intervention and control group in the percent of participants who reported injuries, or the total number of injuries reported: 28% of participants in each group reported injuries in the previous 12 months. In the intervention group, 55% of the injuries were attributed to sports or physical activity, and in the control group 30% of the injuries were attributed to sports or physical activity; however, this difference was not statistically significant. Another notable result is that the largest proportion of injuries in both the intervention and control group was attributed to sports or physical activity.

Two groups of participants in another controlled study were asked to engage in 60-75 minutes of resistance training 3 days per week over a period of 18 months. Another two groups did not receive an activity promotion intervention. The average compliance to the exercise program was 65% in one activity group and 61% in the other activity group. No injury prevention strategies were described. Personal trainers reported injuries associated with the program, although it is important to note that they did not supervise all exercise sessions. Among the two activity intervention groups, several injuries were reported that were associated

with the intervention: 1 participant had an exacerbation of gout of the foot, 2 participants had aggravated knee or hip pain, 2 participants sustained lower back injuries, 2 participants experienced aggravation of previous shoulder injuries, and 3 participants had an inguinal hernia. Assuming that each injury was reported by a different participant, this represents 11% of the intervention group. The authors did not report whether any exercise-related injuries were sustained by participants in the control groups (Kukuljan et al., 2009).

In the study by King et al. (2007), participants received counseling over the telephone to engage in unsupervised endurance exercise training (primarily walking) for at least 30 minutes 3 days per week. The control group did not receive an exercise prescription. No injury prevention strategies were described. At each telephone contact, participants were asked to report whether they had experienced injuries that interfered with their ability to participate in the program. The authors reported that 22% of participants in the activity intervention groups experienced physical activity related "injuries" including muscular fatigue, strain or soreness. The authors did not report whether any exercise-related injuries were sustained by participants in the control group.

One study involved an investigation of the effects of a 12-month unsupervised intervention in which participants were taught functional exercises to improve balance and strength that could be incorporated into daily activities (PA1). A second group (PA2) participated in a structured balance and strength exercise program 3 days per week, and a third group (PA3) participated in gentle flexibility exercises. No injury prevention strategies were reported, and the authors did not report the methods by which injuries were measured. Although participants in the first intervention group increased their levels of physical activity, they completed only 33% of the prescribed exercises. One participant in each of the PA1 and PA2 groups experienced an adverse event that was attributed to the exercise program; one was a pelvic stress fracture and one was a groin strain. Therefore, approximately 1% of participants in each group reported exercise-related injuries (Clemson et al., 2012).

A second study involved a comparison of four different groups over a period of 12 months. Participants engaged in either walking or swimming for 60 minutes, 3 days per week, and half of the participants in each group received an additional behavioural intervention component. Participants who did not receive the behavioural intervention were given written materials that included safety information, but it was not reported whether the behavioural intervention included a safety component. The authors indicated that injuries were recorded, but they did not specify the methods by which injuries were measured. The number of exercise sessions completed was approximately 75% across the four groups. No exercise-related injuries were reported among participants in the walking groups. Among participants in the swimming groups, the authors reported that one participant (2% of the group) developed an injury: symptoms from a pre-existing shoulder injury. During the second, unsupervised phase of the intervention, one participant in the walking group developed ankle soreness, and 2 participants in the swimming group developed shoulder problems. These symptoms were described as injuries by the authors (Cox et al., 2008).

In the remaining 7 studies, the authors reported that no injuries occurred (or were reported) during physical activities promoted as part of the intervention. In four of these studies, the prescribed physical activities included a combination of aerobic, strength, balance, flexibility and/or posture exercises; all of these interventions were supervised, or included both supervised and unsupervised components (Baker et al., 2007; Bonnefoy et al., 2012; Kemmler et al., 2010; Kloubec et al., 2012). The participants in the study by Vogel et al. (2011) only engaged in aerobic exercise on a cycle ergometer, and the type of prescribed physical activity was not reported in two studies (Bennett et al., 2008; Kerse et al., 2005).The duration of these interventions ranged from 9 weeks to 18 months. Only 2 of these 7 studies included information to suggest that injury prevention strategies were imparted to the participants (Bennett et al., 2008; Bonnefoy et al., 2012). Among the three studies that reported adherence to the intervention, the average compliance to the exercise prescription ranged from 42% to 100% across studies (Bonnefoy et al., 2012; Kemmler et al., 2010; Vogel et al., 2011). Four of the studies included no information about the methods used to assess injuries; however, in the other 3 studies it was clear that all participants in the study were questioned about any injuries they incurred as a result of participating in the intervention (Baker et al., 2007; Bennett et al., 2008; Kerse et al., 2005).

Eight of 12 studies that included adults over the age of 65 years included participants who were of healthy weight in addition to those who were overweight and obese. The remaining 4 studies did not contain information about the weight of the participants. Only Campbell et al. (2012) assessed whether there was an association between weight and injury. Neither body mass nor BMI were significant predictors of injury in the regression analysis.

3.5.4 Injury Outcomes - Participants with Health Conditions

In 14 of 23 studies that included participants with specific health conditions, one or more participants were reported to have experienced injuries. In the remaining 9 studies, the authors stated that no injuries occurred (or were reported) during the physical activities promoted as part of the intervention. In order to investigate whether the results varied depending on the type of health condition, studies that included participants with cancer and diabetes are reported separately.

Cancer

In 7 of 9 studies that included cancer patients, one or more participants were reported to have experienced injuries. In the other two studies, the authors stated that there were no injuries associated with participation in the intervention.

The study by Schmitz et al. (2005) was the only one in which it was clear that both the exercise intervention group and the no-exercise control group were asked to report study-related injuries. Participants in the intervention group engaged in weight-training exercises over the first 6 months, and then the control group also began the weight-training program. The authors reported that the first 13 weeks of the program were

supervised by certified exercise trainers so that participants could learn how to exercise safely. The mean rate of adherence was 92%, and only one participant attended less than 80% of the prescribed exercise sessions. All participants were asked to report whether or not they had sustained any injuries, the type of injury, and the extent to which the injury was caused by participation in the study. In the first 6 months, four participants in the intervention group (11% of the group) reported back injuries, and one participant in the control group (3% of the group) reported shoulder tendonitis that was attributed to participation in the study. In the following 6 months, after the control group began the weight training program, 2 participants in the intervention group (5%) reported back injuries, 1 reported a wrist injury (3%), and 1 reported leg pain (3%). In the control group, 2 participants reported back injuries (6%), 1 reported heel spurs (3%), 3 reported ankle injuries (9%), and 1 reported a rotator cuff injury (3%).

Anderson et al. (2012) compared two physical activity interventions and did not include a no-exercise control group, and in two other studies the authors did not report whether injuries were sustained by participants in the control group (Dodd et al., 2010; Irwin et al., 2008). One intervention was an 18-month resistance training program with supervised and unsupervised components (Anderson et al., 2012), one was a 12-month unsupervised aerobic exercise intervention (Dodd et al., 2010), and one was a 6 month program in which participants exercised mainly by walking, but they could also choose other activities such as swimming or jogging (Irwin et al., 2008). Two of the three studies included safety or injury prevention strategies (Anderson et al., 2012; Irwin et al., 2008). The rates of adherence to the prescribed exercises ranged from 61% to 87% across studies. In the study by Anderson et al. (2012) injuries were reported through a safety and monitoring board. Dodd et al. (2010) asked participants by telephone whether they had sustained any injuries during the exercise sessions. Irwin et al. (2008) did not report the methods by which participants were asked to report injuries, however they stated that participants who reported injuries were asked to describe the cause of the injury.

Anderson et al. (2012) stated that two participants (2% of the sample) experienced injuries related to the resistance training program: 1 participant experienced a foot stress fracture and 1 participant experienced pectoral muscle pain. However, the authors did not report the study group to which these participants belonged. Two participants in the study by Irwin et al. (2008) reported that they experienced plantar fascitis as a result of participating in the program. This represents 6% of the intervention group. Dodd et al. (2010) reported the following injuries that were sustained during the aerobic exercise sessions: sciatica (n = 16), arm discomfort (n = 4), knee discomfort (n = 10), and foot discomfort (n = 8). The authors also reported that some participants experienced hip pain, but did not report the number of participants. It is not clear whether some participants experienced more than one of these symptoms. There were a total of 69 participants in the two physical activity intervention groups.

Three studies involved a pre-post study design in which the same group of participants was measured before and after the intervention. One was a 6-month aerobic exercise intervention with supervised and unsupervised components (Campbell et al., 2012), one was a 3-month supervised resistance training program (Rajotte et al., 2012), and one was an unsupervised walking program of unspecified duration (Wilson et al., 2006). Campbell et al. (2012) reported that 43% of participants attended more than 80% of

the exercise sessions, Rajotte et al. (2012) reported that 88% of the participants attended more than half of the exercise sessions, and Wilson et al. (2006) reported that 65% of the prescribed exercise sessions were documented in the participants' diaries. Only one of these reports included information about injury-prevention strategies (Rajotte et al., 2012). In two of the three studies, participants completed a questionnaire or checklist to report exercise-related injuries (Rajotte et al., 2012; Wilson et al., 2006), but Campbell et al. (2012) did not report the methods by which injuries were assessed.

Campbell et al. (2012) reported that one participant fell from a treadmill and sustained an upper arm fracture. This represents 7% of the study group. Wilson et al. (2006) reported that one participant tripped while walking and sustained minor injuries, but no details were reported about the nature of the injuries. This represents 4% of the study group. Finally, Rajotte et al. (2012) reported that 10% of the participants sustained injuries during the resistance training sessions. Five events were related to weight-lifting (pulled back muscle, sore hips, too much shoulder effort, sore wrist, legs and arms out of shape), and 3 participants reported symptoms from previous conditions that affected their ability to participate in the intervention or that were aggravated by their participation (chronic vertigo, bursitis, Baker's cyst).

In the remaining two studies, the authors stated that there were no injuries associated with participation in the intervention. One was a 12-month resistance training program that involved supervised and unsupervised components, and that incorporated safety measures. The average attendance across the supervised and unsupervised components was approximately 60%. The authors stated that participants reported any intervention-related injuries in exercise logs (Winters-Stone et al., 2011). The second intervention was a 12-week unsupervised walking program. The authors reported that 88% of the participants who completed the intervention met or exceeded the exercise requirements. No injury-prevention strategies were reported, and the authors did not report the methods that were used to assess injuries (Truong et al., 2011).

Diabetes

In 5 of 8 studies that included participants with diabetes, one or more participants were reported to have experienced injuries. In the other three studies, the authors stated that there were no injuries associated with participation in the intervention.

Two studies involved a comparison of an exercise intervention to a no-exercise control group. One was a 4-month weight training intervention with both supervised and unsupervised components (Plotnikoff et al., 2010), and the other was a 2-year unsupervised intervention involving habitual activities such as walking or stair-climbing (Wisse et al., 2010). The authors of these studies did not report whether injury-prevention components were included as part of the interventions, or the methods by which injuries were assessed. Eight participants (44% of the intervention group) in the weight-training study experienced intervention-related injuries that interfered with their ability to exercise (3 knee, 3 shoulder, 1 back, 1 backside); the authors did not report whether participants in the control group sustained injuries (Plotnikoff et al., 2010).

Wisse et al. (2010) reported that 34% of participants in the intervention group and 35% of participants in the control group experienced injuries related to physical activity.

Three studies involved a comparison of two or more different physical activity interventions over a period of 12 months. Two were supervised interventions involving aerobic and resistance training (Balducci et al., 2010; Praet et al., 2008); the type of physical activity was not reported in the third study (Kinmonth et al., 2008). Only Balducci et al. (2008) specified that injury-prevention strategies were incorporated. In two of the three studies, the methods used to assess injuries were described. Balducci et al. (2008) stated that injuries were reported by completing a standard form, and Kinmonth et al. (2008) stated that injuries were reported using contact registers and questionnaires.

Kinmonth et al. (2008) reported that approximately 10% of participants in each of the three intervention groups had received medical attention for pain or injury that occurred during or after physical activity in the 12-month period. Praet et al. (2008) reported 15 intervention-related adverse events in one intervention group, and 12 intervention-related adverse events in the second intervention group. There were a total of 52 participants in the study, and the authors did not report whether some participants reported multiple adverse events. Across groups, the injuries included shoulder pain/chronic tendinopathy of the rotator cuff (n = 1), aggravation of lower back pain (n = 4), aggravation of pre-existing knee or hip osteoarthritis (n = 10), shin splints/lower leg pain (n = 1), chronic tendinopathy of the Achilles tendon or plantar facia (n = 4), and other musculoskeletal discomfort (n = 6). In the study by Balducci et al. (2008), one group reported 34 intervention-related injuries (9 shoulder pain/chronic tendinopathy of rotator cuff, 6 aggravation of lower back pain, 5 aggravation of pre-existing knee/hip osteoarthritis, 7 shin splints/lower leg pain, 7 other musculoskeletal discomfort). The authors did not report whether some participants reported multiple injuries. However, if we assume that each symptom was reported by a different participant, this represents 12% of the group. The second intervention group reported 20 intervention-related injuries (5 shoulder pain/chronic tendinopathy of rotator cuff, 2 aggravation of lower back pain, 2 aggravation of pre-existing knee/hip osteoarthritis, 3 shin splints/lower leg pain, 8 other musculoskeletal discomfort). If we assume that each symptom was reported by a different participant, this represents 7% of the group. There was not a significant difference between groups in the overall number of adverse events.

In the remaining three studies, the authors stated that there were no injuries associated with participation in the intervention. One was a 9-month unsupervised aerobic exercise intervention (Wu et al., 2011), one was an 8-week supervised resistance training program (Hazley et al., 2010), and one was an unsupervised 3-month program involving both aerobic and resistance training (Krousel-Wood et al., 2008). None of these interventions were reported to have involved injury-prevention components, and only one report described the methods by which injuries were assessed; Krousel-Wood et al. (2008) stated simply that injuries were monitored through an electronic information system and participant feedback. Hazley et al. (2010) reported 100% attendance at the exercise sessions, and the other two reports did not include data on the rate of adherence.

Other Health Conditions

Six studies included participants with other health conditions including osteoarthritis (Fitzgerald et al., 2011), heart failure (Dracup et al., 2007), one or more diseases or risk factors (Goodrich et al., 2007; Lund et al., 2009), and schizophrenia (Dodd et al., 2011; Marzolini et al., 2009).

Fitzgerald et al. (2011) assessed the effects of two different physical activity interventions for participants with osteoarthritis over a period of 12 months. Both interventions involved muscle strengthening and stretching, and one of the interventions also included agility and perturbation training (i.e., applying destabilizing forces through the use of tiltboards). The authors did not report whether injury-prevention strategies were included, or the methods by which injuries were assessed. The authors stated that there were no intervention-related injuries that required a physician referral.

Dracup et al. (2007) investigated the effects of a 6-month unsupervised aerobic and resistance training intervention for participants with heart failure. The authors did not report whether injury-prevention strategies were included or the methods by which injuries were assessed, and stated that there were no exercise-related injuries.

Two interventions were conducted with individuals who had one or more diseases or risk factors for diseases associated with obesity (e.g., diabetes, coronary artery disease). Lund et al. (2008) evaluated the effects of two different physical activity promotion programs over a period of 4-months, but did not report the type of physical activity that was promoted, whether injury-prevention strategies were incorporated, or the specific methods by which participants self-reported injuries associated with the program. Three participants in one intervention group (2% of the group) and four participants in the second intervention group (3% of the group) reported minor injuries that they sustained as a result of participating in the intervention. These injuries included knee and ankle sprains. Goodrich et al. (2007) assessed the effects of three different methods of promoting increased physical activity through walking over an 18 month period. Safety components included counseling participant to gradually increase their levels of physical activity, and providing participants with written instructions about how to warm-up and stretch. The authors stated that research staff were required to report safety concerns to one of the principal investigators, and details were provided about the methods by which adverse events were coded. However, the specific methods by which injuries were observed or reported were not described. No serious study-related musculoskeletal adverse effects were reported, and 9 non-serious study-related musculoskeletal events were reported (6% of the sample). Five of these events involved bone or connective tissue in the leg or foot, and four events involved muscle cramping or soreness.

Two interventions were conducted with small samples of individuals ($n < 15$) who had received a diagnosis of schizophrenia. One was a 6-month supervised aerobic exercise intervention (Dodd et al., 2011), and one was a 3-month intervention involving aerobic and resistance training with supervised and unsupervised components (Marzolini et al., 2009). The authors did not report whether injury-prevention strategies were incorporated in the interventions. Dodd et al. (2011) stated that each participant was asked whether they had experienced injuries before and after each exercise session, and that no injuries were reported.

Marzolini et al. (2009) did not report the methods by which injuries were assessed, and stated that there were no "significant" injuries related to participation in the intervention.

3.6 Results of Key Informant Interviews

Interviews were conducted with representatives of organizations that promote physical activity within BC communities. Bryna Kopelow, Program Developer and Project Team Manager, provided information about Action Schools BC! Erica Timmerman, Communications Coordinator with the BC Medical Association, provided information about the Be Active Every Day program. Brian Evernden, Policy Analyst at the Ministry of Health, provided information about the Prescription for Health program. Finally, Arlene Cristall, Mary Hinchliffe, and Pam Narang provided information about Shapedown BC.

Action Schools BC! is a school-based program in which schools create an action plan for increasing physical activity in 6 different zones (school environment, physical education, classroom action, family and community, extra-curricular, and school spirit). Over 60,000 students in kindergarten to Grade 9 have participated in the program from over 1,400 schools across BC. Examples of physical activities include a playground activity circuit, and the use of equipment such as skipping ropes, balls, exercise bands and sidewalk chalk. A component of the program is an assessment of the safety of the school environment. Specific injury prevention messages include the use of appropriate footwear for physical activity, and ensuring that jewelry will not pose a risk of injury. Although four journal articles on the effects of the program were identified in the database search for this review, these articles did not contain data on whether any of the participants experienced injuries. This program will continue to be offered to BC students in the future.

Be Active Every Day is an initiative of the BC Medical Association. It is a school-based intervention in which physicians make three visits to schools in their communities. Physicians were encouraged to promote the 5-2-1-0 approach (5 fruits/vegetables, less than 2 hours of screen time, 1 hour per day of physical activity, 0 sugared drinks), and to engage the children in some kind of activity, but each physician delivered messages in his/her own way. Examples of activities included a boot camp, a soccer game, and playing outdoors with paper airplanes. Children were given equipment such as bicycle lights and skipping ropes. Approximately 1,700 students, from kindergarten to high school, at 14 schools across BC have participated in the program. The program does not include any injury-prevention strategies or messages, and no data have been collected regarding the effects of the program. However, some teachers expressed concerns that the children were using skipping ropes as whips. The program coordinators are planning to continue the program in the future based on the feedback that they have received from physicians.

The Shapedown BC program uses a multidisciplinary approach to promoting healthy weight that includes nutritional advice, psychological screening and support, and a physical exercise program through the YMCA. Eligible participants are between the ages of 6 and 17 years, have a BMI at or above the 95th percentile, and make a commitment to attend the 10-week program. The program includes parental involvement, and encourages children and families to enjoy more active living including less vigorous activities such as walking and non-competitive sports. An evaluation report was received from the key informants that indicated that

the program was successful in achieving weight reduction and improving certain biochemical indicators in children in the short-term. One of the key informants mentioned a recent episode of an ankle fracture that occurred while a participant was exercising at the YMCA. No data were identified in the database search regarding whether the participants of the Shapedown BC program experienced injuries. While the informants agreed with the importance of a focus on injury prevention in healthy weight promotion, they stressed the importance of not enhancing an already elevated fear of injury from physical activity among parents and children.

Prescription for Health is in initiative of Healthy Families BC (Ministry of Health). Physicians conduct a personal health assessment with patients who belong to one of four at-risk populations (smoking, unhealthy eating, physical inactivity, obesity). The assessment can be completed as part of proactive care or in response to a request from a patient. Physicians have a prescription pad that lists available services, and check off the services that their patients need. Patients can be referred to a free lifestyle support service to assist them in achieving their goals. Over 3,000 physicians have participated, and over 165,000 assessments were completed across BC in the previous year. Although there are no age restrictions, mainly adults have participated. The program does not include any injury-prevention strategies or messages, and no data have been collected regarding the effects of the program, although an evaluation is planned for the future. This program is ongoing.

4.0 Discussion

The purpose of this report was to summarize and synthesize research on the injury consequences of promoting physical activity. In half of the studies in which physical activity was promoted, none of the participants were reported to have sustained injuries. Injuries were least likely to be reported in studies that included samples of children and adolescents. Among the studies in which one or more participants were injured, the number of participants who sustained injuries was typically small. In many studies, the proportion of participants who were injured as a result of physical activity was under 10% (typically involving only 1 or 2 participants), and most of the reported injuries were minor (e.g., muscle strain, sprains). In the only study in which rates of injury were reported with respect to the total exposure to physical activity, Collard et al. (2010) reported rates of 0.33 injuries per 1,000 hours of activity for the high-active group, and 0.37 injuries per 1,000 hours of activity for the low-active group.

Among studies in which higher proportions (> 10%) of participants were reported to have sustained injuries, several observations can be made. First, the types of events that were reported as injuries often included muscle cramping, discomfort, soreness, or pain (e.g., Balducci et al., 2010; King et al., 2007; Praet et al., 2008; Rajotte et al., 2012). In several studies, the authors did not define the types of symptoms that were to be considered injuries (e.g., Schmitz et al., 2005; Wisse et al., 2010), so it is unclear whether the reported injuries included symptoms such as soreness or discomfort. The authors did not provide details about these symptoms, but it may be that they were examples of what is known as Delayed Onset Muscle Soreness (DOMS). According to the American College of Sports Medicine, although DOMS is a result of microscopic

tears in muscle fibres, it is considered a normal part of physical activity whose symptoms dissipate within a few days without requiring medical attention (Braun & Sforzo, 2011). Therefore, these symptoms may be considered extremely mild forms of injury, or it may be inappropriate to describe these symptoms as injuries.

Another observation is that among the studies in which higher proportions of participants experienced injuries, the source of the injuries was more likely to include any form of physical activity. On the other hand, among the studies in which lower proportions of participants experienced injuries, the source of the injuries were mainly limited to the exercise sessions that were required as part of the intervention. Furthermore, the total duration of the physical activity promotion tended to be longer among the studies in which higher proportions of participants were injured. Therefore, among the studies in which a higher proportion of participants experienced injuries related to physical activity, the total "exposure" to physical activity was often greater. In other words, although the proportion of participants experiencing injuries was higher in some studies, it is possible that the actual rate of injury in terms of the total hours of exposure to physical activity was comparable to those studies in which lower proportions of participants were injured.

Two additional factors appeared to be associated with the proportion of participants who were reported to have experienced injuries. Studies that included adults over the age of 65 years and that included participants with diabetes were among those in which higher proportions of participants experienced injuries. Also, studies in which *lower* proportions of participants experienced injuries were *less* likely to include details about the methods by which injuries were reported. If the reports did not clearly describe the methods by which injuries were assessed, it is not possible to determine whether the participants did not sustain any injuries or whether the participants did not report injuries because they did not have the opportunity to do so. Reports of injury may have been lower in the studies in which injuries were not systematically assessed. On the other hand the issue could be related to the quality of the reporting rather than the quality of the assessment. Some researchers may have systematically assessed injuries, but because injury was not one of the primary outcomes, they did not report the methods related to injury assessment. It is also important to note that several studies in which no injuries were reported did include a systematic assessment of injuries.

It was expected that the type of physical activity that was promoted as part of the intervention (i.e., aerobic, resistance, team sports), as well as the inclusion of injury-prevention strategies in the intervention, might have been associated with the number of injuries reported. However no pattern was observed across studies with respect to these factors. Several studies in which no injuries were reported did not contain any information about injury prevention, and several studies in which a high proportion of injuries were reported did include injury-prevention strategies. Again, this may be related to the reporting of the study methods. It is possible that more of the interventions included injury-prevention components but that they were not reported. Furthermore, it was unclear whether many of the injury-prevention strategies were evidence-based.

Taken together, the results of this review suggest that increasing physical activity is unlikely to lead to a substantial increase in the risk of severe injury, and that a small proportion of individuals who increase their

physical activity levels can be expected to experience minor injuries. However, a number of methodological limitations of the studies greatly limit our ability to be confident in this interpretation of the results. These limitations are discussed in the following section.

Based on the results of this review, it is not possible to draw conclusions about whether individuals who are overweight or obese are more likely to sustain injuries from physical activity compared with those who are of healthy weight. In one study in which the association between BMI and injury was assessed among participants who were overweight or obese, those with a higher BMI were more likely to experience injuries (Janney & Jakicic, 2010). However, Campbell et al. (2012) did not find a significant association between BMI and injury. The majority of the studies in this review included participants who were overweight and/or obese, so it is possible that the results of the review apply to individuals in all weight categories. However, it is also possible that most of the reported injuries were sustained by participants with a higher body weight. Unfortunately, the authors of the studies did not report the weight of the participants who sustained injuries.

Given that the results of previous cross-sectional studies have suggested that increased physical activity is associated with higher injury rates (Field et al., 2011; Hootman et al., 2001), it was somewhat surprising that the results of the current review found relatively low rates of injury among participants who were instructed to increase their physical activity. There are several possible explanations for this discrepancy. First, as previously mentioned, many studies may not have included a systematic assessment of injuries, limiting the opportunities for participants to report injuries. Second, among studies in which the rate of adherence to the prescribed exercise was reported, it was clear that participants did not complete all of the prescribed exercises, and the rate of adherence in some studies was very low. Therefore, many of the participants may not have significantly increased their levels of physical activity. Third, the discrepancy may reflect a publication bias. Among studies in which higher rates of injury were hypothesized among participants who increased their levels of physical activity, those whose results were not consistent with the hypotheses may not have been published or even submitted for publication. The majority of the studies included in this review assessed the effects of physical activity on other outcomes such as health and weight. The primary outcomes in most of the studies were not related to injury but instead focused on health, weight, and/or physical activity levels, so these studies were published despite the fact that few injuries were observed.

4.1 Critique of the Literature and Recommendations for Future Research

Overall, the quality of the reporting of participant characteristics was adequate. Most studies (> 95%) included the mean age of the participants, the sex distribution, and a description of the criteria by which participants were deemed eligible to participate in the study. The majority of studies (80%) included basic descriptive data on the participants' weight before the intervention; however, it would be useful if future researchers would report the proportion of participants in each weight category (underweight, healthy weight, overweight, obese) to better characterize the sample. The majority of studies (82%) included basic descriptive data on the participants' physical activity levels before the intervention; however, a great deal of variability was observed in the methods used to assess physical activity, limiting our ability to make comparisons across studies. Data on the socioeconomic status and ethnicity of the participants were missing

from approximately half of the studies. If these participant characteristics are not reported, it is not possible to determine to which portions of the population the results can be generalized.

Overall, the quality of the reporting of intervention characteristics was adequate. Most studies included information about the type of prescribed exercises (i.e., aerobic, resistance), the frequency of exercise, and the duration of the intervention. Studies were somewhat less likely to include information about the length of the prescribed exercise sessions, and the intensity of the prescribed exercise. If these intervention characteristics are not reported, it limits our ability to compare the results across studies and the ability of future researchers to replicate the results.

In terms of answering the question as to whether increasing physical activity increases injury risk, there are serious gaps in the literature that limit our ability to address this question.

A major limitation of the literature generally was that few studies in which physical activity was promoted included data regarding the potential harms or negative consequences of participating in physical activity. Based on a sub-sample of articles that were screened for inclusion in this review, only approximately 10% of the articles that described an intervention to promote physical activity included data on adverse events associated with the intervention. Of those, fewer than half of the articles contained information about whether the participants sustained injuries, and fewer than half of the articles with data on injuries clearly referred to injuries that were a result of participating in physical activity. Foster et al. (2005) conducted a review of randomized controlled trials of interventions promoting physical activity that were published prior to 2004. Of 19 studies that met the strict inclusion criteria for the review, only 8 included data on adverse events. Pollack (2009) also noted the lack of attention to injury prevention among those who promote physical activity. The results of the key informant interviews are consistent with the literature in that injury prevention does not play a prominent role in community-based efforts to promote physical activity. Given the results of previous research suggesting an association between physical activity and injury (e.g., Hootman et al., 2001), particularly among those who are overweight (McHugh, 2010), researchers who evaluate the effects of interventions to promote physical activity are strongly encouraged to measure participant injuries.

It is vital that researchers clearly indicate the methods by which injuries are assessed, and to use reliable and valid measures. In most studies included in this review, the authors did not provide information to clearly indicate how injuries were measured. In many cases, it was unclear whether injuries were systematically assessed, and whether all participants had the opportunity to report injuries. Among the studies in which no participants were reported to have experienced injuries, several authors included ambiguous statements such as “no injuries were reported” or “no injuries were observed” and provided no information about whether (or how) injuries were assessed (Campbell et al., 2007; Lubans et al., 2011; Vogel et al., 2011). It is unclear whether no injuries were reported because participants/trainers did not have an opportunity to report them, or because participants did not sustain any injuries.

A great degree of variability was observed across studies as to the types of injuries that were reported. For example, some studies included injuries that required medical attention (e.g., Fitzgerald et al., 2011) or that

interfered with the participants' ability to exercise or engage in daily activities (e.g., Campbell et al., 2012; Collard et al., 2010), some studies indicated that there were no "major" or "serious" injuries but did not specify how they determined what constituted a major or serious injury (e.g., Hemmingsson et al., 2009; Maddison et al., 2011), some studies reported only injuries that resulted in participant withdrawal from the study (e.g., Messier et al., 2010), and some studies described muscle pain, soreness, or discomfort as injuries (e.g., Anderson et al., 2012; King et al., 2007). Several studies provided no information about how injuries were defined (e.g., Beaulac et al., 2011; Kloubec et al., 2012). This variability and lack of information on the definition of injury greatly limits our ability to determine the gravity of the risk of injury associated with physical activity, and our ability to compare results across studies. In the future, researchers should define what constitutes an injury a priori, and clearly state this definition in their reports. Furthermore, in order to better evaluate risk, it would be useful to discriminate among injuries of different severity.

It would be ideal to measure injuries associated with the promoted physical activity, as well as injuries associated with other types of physical activity. This would require measuring physical activity in which the participants engage outside of the intervention, and would allow for a comparison of activity-related injuries between intervention and control groups. It may be that some participants experience injuries while they are exercising, but it is possible that they are at an overall reduced risk of activity-related injury due to factors such as improved strength and balance (Benetou et al., 2011). Few studies in this review included data on the amount of physical activity in which participants' engaged that was not part of the intervention, and among RCTs that included a no-exercise control group, few studies assessed whether participants in the control group sustained injuries.

A related point is that researchers should report rates of injury with respect to the total amount of exposure to physical activity. Among the studies in the current review, most authors reported the proportion of participants who experienced injuries, or the raw numbers of injuries reported. However, the interventions varied in terms of the number and length of the exercise sessions, and the total duration of the exercise intervention. Also, only approximately half of the studies included data on the actual levels of physical activity in which participants engaged during the intervention, or whether the participants significantly increased their physical activity levels. To illustrate this point, if 10 participants are injured over a 2-month period during which they engage in 150 minutes of physical activity per week, this is a much higher rate of injury compared to a situation in which 10 participants are injured over a 2-year period during which they engage in 300 minutes of physical activity per week. Furthermore, the results of the studies indicated that not all participants adhered to the exercise prescription, highlighting the importance of measuring the actual physical activity levels of the participants when reporting injury data. Providing rates of injury in terms of hours of exposure would control for these variables.

Few studies included information about whether safety or injury-prevention strategies were incorporated into the interventions. This may reflect a lack of attention to injury prevention among those who promote physical activity, or it may simply be that the injury prevention strategies were not described in the reports. Information about injury-prevention strategies should be included in future research in which injury rates are reported, because these would be expected to impact the frequency with which the participants sustain

injuries. Furthermore, such data would add to the evidence base regarding the effectiveness of various injury-prevention strategies.

Additional research is needed to determine whether overweight or obese individuals are at a greater risk of exercise-related injuries compared with individuals of healthy weight. This issue is of particular concern because physical activity is recommended as part of a weight reduction strategy. Given that some previous research suggested that overweight individuals may be at an increased risk of injury (McHugh, 2010), and most of the studies in the review included participants in different weight categories, it was surprising that the association between weight and injury was not evaluated in more studies. It is also important to note that some studies have found that weight is not associated with the risk of injury (Field et al., 2011; Warsh et al., 2010). Additional research could help to establish whether (and how) physical activity interventions should be tailored to an individual's weight.

There is a need for research that investigates the risk of injury associated with different forms of physical activity. The results of some cross-sectional studies suggested that the risk of injury varied according to the type of physical activity (Centers for Disease Control and Prevention, 2006; Field, et al., 2011; Lowry et al., 2007). For example, Field et al. (2011) found that the frequency of running, basketball, and cheerleading/gymnastics was associated with an increased risk of stress fractures among adolescent girls, but other high impact activities (soccer, tennis, volleyball) were not associated with an increased risk of stress fracture. It was not possible to determine whether the type of activity was associated with injury risk based on the evidence included in this review.

4.2 Recommendations for Policy and Practice

Because of the numerous methodological limitations of the literature on the association between physical activity and injury, and the variability in the results, it would not be appropriate to make strong recommendations for policy or practice based on the currently available evidence. The key message from this review is that more attention must be given to injury prevention and the potential injury consequences of physical activity. This message applies to those who promote physical activity, as well as to those who conduct research on the effects of physical activity promotion.

Bearing in mind the limitations of the evidence, the results of this review suggest that increasing physical activity is unlikely to increase the risk of severe injury, and that a small proportion of participants experience minor injuries. Therefore, individuals who seek to improve their health by choosing a more active lifestyle, as well as those who promote physical activity, can rest assured that injury is not an inevitable consequence of physical activity.

On the other hand, some of the participants in the reviewed studies did experience minor injuries as a result of participating in physical activity, and a few participants experienced more serious injuries, such as fractures. Also, some previous research suggests that those who participate in more physical activity are at a greater risk of injury, and that some forms of physical activity are associated with a greater risk of injury. These observations suggest that injury prevention must play a role within individual and community-based efforts to increase physical activity. Furthermore, the risk of strains, sprains, or fractures associated with

physical activity must be weighed against the risk of diabetes, cardiovascular disease, and other serious health conditions associated with obesity and a sedentary lifestyle.

Efforts should be made to educate researchers and practitioners who promote physical activity about the importance of injury prevention. Professionals and organizations who promote physical activity should ensure that they are educated on evidence-based strategies for preventing injuries associated with physical activity, and ensure that their clients are aware of potential risks of injury associated with a particular activity and the strategies that can be used to avoid injury. Progress in this area would likely benefit from increasing collaborations between injury-prevention specialists and physical activity specialists.

References

*Andersen, E., Burton, N.W., & Anderssen, S.A. (2012). Physical activity levels six months after a randomized controlled physical activity intervention for Pakistani immigrant men living in Norway. *International Journal of Behavioral Nutrition and Physical Activity, 9: 47.*

*Anderson, R.T., Kimmick, G.G., McCoy, T.G., et al. (2012). A randomized trial of exercise on well-being and function following breast cancer surgery: The RESTORE trial. *Journal of Cancer Survivorship, 6,* 172-181.

*Baker, M.K., Kennedy, D.J., Bohle, P.L., et al. (2007). Efficacy and feasibility of a novel tri-model robust exercise prescription in a retirement community: A randomized controlled trial. *Journal of the American Geriatrics Society, 55,* 1-10.

*Balducci, S., Zanuso, S., Nicolucci, A., et al. (2010). Effect of an intensive exercise intervention strategy on modifiable cardiovascular risk factors in subjects with type 2 diabetes mellitus. *Archives of Internal Medicine, 170,* 1794-1803.

*Beaulac, J., Krisjansson, E., & Calhoun, M. (2011). 'Bigger than hip-hop?' Impact of a community-based physical activity program on youth living in a disadvantaged neighborhood in Canada. *Journal of Youth Studies, 14,* 961-974.

Benetou, V., Orfanos, P., Benetos, I.S., et al. (2011). Anthropometry, physical activity and hip fractures in the elderly. *Injury, 42,* 188-193.

*Bennett, J.A., Young, H.M., Nail, L.M., Winters-Stone, K., & Hanson, G. (2008). A telephone-only motivational intervention to increase physical activity in rural adults: A randomized controlled trial. *Nursing Research, 57,* 24-32.

*Bonnefoy, M., Boutitie, F., Mercier, F., et al. (2012). Efficacy of a home-based intervention programme on the physical activity level and functional ability of older people using domestic services: A randomized study. *The Journal of Nutrition, Health & Aging, 16,* 370-377.

Braun, W., & Sforzo, G. (2011). ACSM information on delayed onset muscle soreness. Retrieved April 10, 2013 from http://www.acsm.org/docs/brochures/delayed-onset-muscle-soreness-(doms).pdf.

Brown, T., & Summerbell, C. (2009). Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: An update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. *Obesity Reviews, 10*, 110-141.

*Campbell, K., Foster-Schubert, K., Xiao, L., et al. (2012). Injuries in sedentary individuals enrolled in a 12-month, randomized, controlled, exercise trial. *Journal of Physical Activity and Health, 9,* 198-207.

*Campbell, K.L., Van Patten, C.L., Neil, S.E., et al. (2012). Feasibility of a lifestyle intervention on body weight and serum biomarkers in breast cancer survivors with overweight and obesity. *Journal of the Academy of Nutrition and Dietetics, 112,* 559-566.

*Campbell, K.L., Westerlind, K.C., Harber, V.J., Bell, G.J., Mackey, J.R., & Courneya, K.S. (2007). Effects of aerobic exercise training on estrogen metabolism in premenopausal women: A randomized controlled trial. *Cancer Epidemiology, Biomarkers, & Prevention, 16,* 731-739.

Canadian Society for Exercise Physiology (2012). Canadian physical activity guidelines. Retrieved November 19, 2012 from http://www.csep.ca/CMFiles/Guidelines/CSEP_PAGuidelines_0-65plus_en.pdf.

Centers for Disease Control and Prevention (2005). Sports-related injuries among high school athletes – United States, 2005-06 school year. *Morbidity and Mortality Weekly Report, 55,* 1037-1040.

Clark, E.M., Ness, A.R., & Tobias, J.H. (2008). Vigorous physical activity increases fracture risk in children irrespective of bone mass. A prospective study of the independent risk factors for fractures in healthy children. *Journal of Bone and Mineral Research, 23,* 1012-1022.

*Clemson, L., Singh, M.A.F., Bundy, A., Cumming, R.G., Manollaras, K., O'Loughlin, P., & Black, P. (2012). Integration of balance and strength training into daily life activity to reduce rate of falls in older people (the LiFE study): Randomised parallel trial. *British Medical Journal, 345:* e4547.

*Collard, D.C.M., Verhagen, E.A.L.M., Chinapaw, M.J.M., Knol, D.K., & van Mechelen, W. (2010). Effectiveness of a school-based physical activity injury prevention program: A cluster randomized controlled trial. *Archives of Pediatric and Adolescent Medicine, 154,* 145-150.

Colley, R.C., Garriguet, D., Janssen, I., Craig, C.L., Clarke, J., & Tremblay, M.S. (2011a). Physical activity of Canadian adults: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Reports, 22,* 1-9.

Colley, R.C., Garriguet, D., Janssen, I., Craig, C.L., Clarke, J., & Tremblay, M.S. (2011b). Physical activity of Canadian children and youth: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Reports, 22,* 1-9.

*Cowan, W., & Foster, B. (2009). The effect of a non-traditional strength training program on the health-related fitness outcomes of youth strength training participants. *ICHPER-SD Journal of Research, 4,* 25-29.

*Cox, K.L., Burke, V., Beilin, L.J. et al. (2008). Short and long-term adherence to swimming and walking programs in older women – The Sedentary Women Exercise Adherence Trial (SWEAT-2). *Preventive Medicine, 46,* 511-517.

Curioni, C.C., & Lourenco, P.M. (2005). Long-term weight loss after diet and exercise: A systematic review. *International Journal of Obesity, 29,* 1168-1174.

*Dodd, M.J., Cho, M.H., Miaskowski, C., et al. (2010). A randomized controlled trial of home-based exercise for cancer-related fatigue in women during and after chemotherapy with or without radiation therapy. *Cancer Nursing, 33,* 245-257.

*Dodd, K.J., Duffy, S., Stewart, J.A., Impey, J., & Taylor, N. (2011). A small group aerobic exercise program that reduces body weight is feasible in adults with severe chronic schizophrenia: A pilot study. *Disability and Rehabilitation, 33,* 1222-1229.

*Dracup, K., Evangelista, L.S., Hamilton, M.A., et al. (2007). Effects of a home-based exercise program on clinical outcomes in heart failure. *American Heart Journal, 154,* 877-883.

Egberts, K., Brown, W.A., Brennan, L., & O'Brien, P.E. (2012). Does exercise improve weight loss after bariatric surgery? A systematic review. *Obesity Surgery, 22*, 335-341.

*Faigenbaum, A.D., McFarland, J.E., Johnson, L., et al. (2007). Preliminary evaluation of an after-school resistance training program for improving physical fitness in middle school-age boys. *Perceptual and Motor Skills, 104,* 407-415.

Field, A.E., Gordon, C.M., Pierce, L.M., Ramappa, A., & Kocher, M.S. (2011). Prospective study of physical activity and risk of developing a stress fracture among preadolescent and adolescent girls. Archives of Pediatrics and Adolescent Medicine, 165, 723-728.

*Fitzgerald, G.K., Piva, S.R., Gil, A.B., et al. (2011). Agility and perturbation training techniques in exercise therapy for reducing pain and improving function in people with knee osteoarthritis: A randomized clinical trial. *Physical Therapy, 91,* 452-469.

Foster, C., Hillsdon, M., Thorogood, M., Kaur, A., & Wedatilake, T. (2005). Interventions for promoting physical activity. *Cochrane Database of Systematic Reviews, Issue 1,* Article No: CD003180.

Gomez, J.E., Ross, S.K., Calmbach, W.L., Kimmel, R.B., Schmidt, D.R., & Dhanda, R. (1998). Body fatness and increased injury rates in high school football linemen. Clinical Journal in Sport Medicine, 8, 115-120.

*Goodrich, D.E., Larkin, A.R., Lowery, J.C., Holleman, R.G., & Richardson, C.R. (2007). Adverse events among high-risk participants in a home-based walking study: A descriptive study. *International Journal of Behavioral Medicine and Physical Activity, 4:20.*

* Hazley, L., Ingle, L., Tsakirides, C., Carroll, S., & Nagi, D. (2010). Impact of a short-term, moderate intensity, lower volume circuit resistance training programme on metabolic risk factors in overweight/obese type 2 diabetes. *Research in Sports Medicine, 18,* 251-262.

Health Canada (2003). *Canadian guidelines for body weight classification in adults*. Retrieved Febrary 7, 2013 from http://www.hc-sc.gc.ca/fn-an/alt_formats/hpfb-dgpsa/pdf/nutrition/weight_book-livres_des_poids-eng.pdf.

Health Canada (2006). It's Your Health: Obesity. Retrieved April 8, 2013 from http://www.hc-sc.gc.ca/hl-vs/alt_formats/pacrb-dgapcr/pdf/iyh-vsv/life-vie/obes-eng.pdf.

*Hemmingsson, E., Udden, J., Neovius, M., Ekelund, U., & Rossner, S. (2009). Increased physical activity in abdominally obese women through support for changed commuting habits: A randomized clinical trial. *International Journal of Obesity, 33,* 645-652.

*Hooker, S.P., Harmon, B., Burroughs, E.L., Rheaume, C.E., Wilcox, S. (2011). Exploring the feasibility of a physical activity intervention for midlife African American men. *Health Education Research, 26,* 732-738.

Hootman, J.M., Macera, C.A., Ainsworth, B.A., Martin, M., Addy, C.L., & Blair, S.N. (2001). Association of physical activity level, cardiorespiratory fitness, and risk of musculoskeletal injury. *American Journal of Epidemiology, 154*, 251-258.

*Irwin, M.L., Cadmus, L., Alvarez-Reeves, M., et al. (2008). Recruting and retaining breast cancer survivors into a randomized controlled exercise trial. *Cancer, 112,* 2593-2606.

*Janney, C.A., & Jakicic, J.M. (2010). The influence of exercise and BMI on injuries and illnesses in overweight and obese individuals: A randomized control trial. *International Journal of Behavioral Nutrition and Physical Activity, 7:1.*

*Kemmler, W., von Stengel, S., Engelke, K., et al. (2010). Exercise, body composition, and functional ability: A randomized controlled trial. *American Journal of Preventive Medicine, 38,* 279-287.

*Kerse, N., Elley, C.R., Robinson, E., & Arroll, B. (2005). Is physical activity counseling effective for older people? A cluster randomized, controlled trial in primary care. *Journal of the American Geriatrics Society, 53,* 1951-1956.

*King, A.C., Friedman, R., Marcus, B., et al. (2007). Ongoing physical activity advice by humans versus computers: The community health advice by telephone (CHAT) trial. *Health Psychology, 26,* 718-727.

*Kinmonth, A., Wareham, N., Hardeman, W., et al. (2008). Efficacy of a theory-based behavioural intervention to increase physical activity in an at-risk group in primary care (ProActive UK): A randomized trial. *Lancet, 371,* 41-48.

*Kloubec, J.A., Rozga, M., & Block, M. (2012). Balance improvements in independent-living elderly adults following a 12-week structured exercise program. *Activities, Adaptation & Aging, 36,* 167-178.

*Krousel-Wood, M.A., Berger, L., Jiang, X., et al. (2008). Does home-based exercise improve body mass index in patients with type 2 diabetes? Results of a feasibility trial. *Diabetes Research and Clinical Practice, 79,* 230-236.

*Krustrup, P., Nielsen, J.J., Krustrup, B.R., et al. (2009). Recreational soccer is an effective health-promoting activity for untrained men. *British Journal of Sports Medicine, 43,* 825-831.

*Kukuljan, S., Nowson, C.A., Sanders, K., & Daly, R.M. (2009). Effects of resistance exercise and fortified milk on skeletal muscle mass, muscle size, and functional performance in middle-aged and older men: An 18-mo randomized controlled trial. *Journal of Applied Physiology, 107,* 1864-1873.

Lowry, R., Lee, S.M., Galuska, D.A., et al. (2007). Physical activity-related injury and body mass index among US high school students. *Journal of Physical Activity and Health, 4,* 325-342.

*Lubans, D.R., Morgan, P.J., Aguiar, E.J., & Callister, R. (2011). Randomized controlled trial of the Physical Activity Leaders (PALs) program for adolescent boys from disadvantaged secondary schools. *Preventive Medicine, 52,* 239-246.

*Lubans, D.R., Sheaman, C., & Callister, R. (2010). Exercise adherence and intervention effects of two school-based resistance training programs for adolescents. *Preventive Medicine, 50,* 56-62.

*Maddison, R., Foley, L., Mhurchu, C.N., et al. (2011). Effects of active video games on body composition: A randomized controlled trial. *American Journal of Clinical Nutrition, 94,* 156-163.

*Marzolini, S., Jensen, B., & Melville, P. (2009). Feasibility and effects of a group-based resistance and aerobic exercise program for individuals with severe schizophrenia: A multidisciplinary approach. *Mental Health and Physical Activity, 2, 29-36.*

McHugh, M.P. (2010). Oversized young athletes: A weighty concern. *British Journal of Sports Medicine, 44,* 45-49.

*Messier, V., Rabasa-Lhoret, R., Doucet, E., et al. (2010). Effects of the addition of a resistance training program to a caloric restriction weight loss intervention on psychosocial factors in overweight and obese post-menopausal women: A Montreal-Ottawa new emerging team study. *Journal of Sports Sciences, 28,* 83-92.

*Nasca, M.M., Zhang, R., Super, D.M., Hazen, S.L., & Hall, H.R. (2010). Increased oxidative stress in healthy children following an exercise program: A pilot study. *Journal of Developmental and Behavioral Pediatrics, 31,* 386-392.

*Norton, L.H., Norton, K.I., Lewis, N., & Dollman, J. (2011). A comparison of two short-term intensive physical activity interventions: Methodological considerations. *International Journal of Behavioral Nutrition and Physical Activity, 8:133.*

*Plotnikoff, R.C., Eves, N., Jung, M., et al. (2010). Multicomponent, home-based resistance training for obese adults with type 2 diabetes: A randomized controlled trial. *International Journal of Obesity, 34,* 1733-1741.

Pollack, K.M. (2009). An injury prevention perspective on the childhood obesity epidemic. *Preventing Chronic Disease, 6:* A107.

*Praet, S.F.E., van Rooij, E.S.J., Wijtvliet, A., et al. (2008). Brisk walking compared with an individualized medical fitness program for patients with type 2 diabetes: A randomised controlled trial. *Diabetologia, 51,* 736-746.

*Puder, J.J., Marques-Vidal, P., Schindler, C., et al. (2011). Effect of a multidisciplinary lifestyle intervention on fitness and adiposity in predominantly migrant preschool children (Ballabeina): Cluster randomised controlled trial. *British Medical Journal, 343:d6195.*

*Rajotte, E.J., Yi, J.C., Baker, S., et al. (2012). Community-based exercise program effectiveness and safety for cancer survivors. *Journal of Cancer Survivorship, 6,* 219-228.

*Robinson, T.N., Matheson, D.M., Kraemer, H.C., et al. (2010). A randomized controlled trial of culturally tailored dance and reducing screen time to prevent weight gain in low-income African American girls: Stanford GEMS. *Archives of Pediatrics and Adolescent Medicine, 164,* 995-1004.

*Rome, A., Persson, U., Ekdahl, C., & Gard, G. (2009). Physical activity on prescription (PAP): Costs and consequences of a randomized, controlled trial in primary healthcare. *Scandinavian Journal of Primary Health Care, 27,* 216-222.

Rose, M.S., Emery, C., & Meeuwisse, W.H. (2008). Sociodemographic predictors of sport injury in adolescents. *Medicine & Science in Sports & Exercise, 40*, 444-450.

*Ross, R., Lam, M., Blair, S.N., et al. (2012). Trial of prevention and reduction of obesity through active living in clinical settings: A randomized controlled trial. *Archives of Internal Medicine, 172,* 414-424.

*Schmitz, K.H., Ahmed, R.L., Hannan, P.J., & Yee, D. (2005). Safety and efficacy of weight training in recent breast cancer survivors to alter body composition, insulin, and insulin-like growth factor axis proteins. *Cancer Epidemiology, Biomarkers & Prevention, 14,* 1672-1680.

Stehr, M.D., & von Lengerke, T. (2012). Preventing weight gain through exercise and physical activity in the elderly. A systematic review. *Maturitas, 72*, 13-22.

*Truong, P.T., Gaul, C.A., McDonald, R.E., et al. (2011). Prospective evaluation of a 12-week walking exercise program and its effect on fatigue in prostate cancer patients undergoing radical external beam radiotherapy. *American Journal of Clinical Oncology, 34,* 350-355.

*Vogel, T., Lepretre, P.M., Brechat, P.H., et al. (2011). Effects of a short-term personalized intermittent work exercise program (IWEP) on maximal cardio-respiratory function and endurance parameters among healthy young and older seniors. *The Journal of Nutrition, Health & Aging, 15,* 905-911.

Warburton, D.E.R., Charlesworth, S., Ivey, A., Nettlefold, L., & Bredin, S.S.D. (2010). A systematic review of the evidence for Canada's physical activity guidelines for adults. *International Journal of Behavioral Nutrition and Physical Activity, 7:39.*

Warsh, J., Pickett, W., & Janssen, I. (2010). Are overweight and obese youth at increased risk for physical activity injuries? *Obesity Facts, 3,* 225-230.

*Weintraub, D.L., Tirumalai, E.C., Farish Haydel, K., et al. (2008). Team sports for overweight children: The Stanford sports to prevent obesity randomized trial (SPORT). *Archives of Pediatric and Adolescent Medicine, 162*, 232-237.

*Wilson, R.W., Taliaferro, L.A., & Jacobsen, P.B. (2006). Pilot study of a self-administered stress management and exercise intervention during chemotherapy for cancer. *Supportive Care in Cancer, 14,* 928-935.

*Winters-Stone, K.M., Dobek, J., Nail, L., et al. (2011). Strength training stops bone loss and builds muscle in postmenopausal breast cancer survivors: A randomized controlled trial. *Breast Cancer Research and Treatment, 127,* 447-456.

*Wisse, W., Rookhuizen, M.B., de Kruif, M.D., et al. (2010). Prescription of physical activity is not sufficient to change sedentary behavior and improve glycemic control in type 2 diabetes patients. *Diabetes Research and Clinical Practice, 88,* e10 – e13.

*Wu, Y., Hwang, C., Chen, C., & Chuang, L. (2011). Home-based exercise for middle-aged Chinese at diabetic risk: A randomized controlled trial. *Preventive Medicine, 52,* 337-343.

Note: Citations identified by an asterisk (*) are those that contain evidence directly relevant to the research question and that are included in the evidence tables in the appendices.

Appendix A. Inclusion criteria.

Any age group

Any country

English language only

Year of Publication 2005 or later

Sample – Selected samples of participants (i.e., samples of the entire population that are not randomly selected or representative) will be ***included*** if the sample is based on age, weight, gender, ethnicity, SES, current activity level, community organization (e.g., school, workplace, community centre), obesity-related disease (e.g., cancer, heart disease, diabetes), psychiatric disorder, or selected samples of obese/overweight participants (e.g., bariatric surgery patients). Selected samples will be ***excluded*** if the profession or activity of the group requires physical activity (e.g., athletes, marathon runners, police, military, fire-fighters). Other examples of selected samples to be excluded include those with intellectual disabilities, spinal cord injuries, traumatic brain injuries, other pre-existing injuries or pain, surgery patients, diseases not related to obesity.

Physical activity promotion – The study must include an intervention or program in which participants are asked or encouraged to increase their current levels of physical activity, or are required to engage in a specific type, length, or intensity of physical activity as part of the research. Such interventions may simply involve providing participants (or participants' parents) with educational information about the importance of physical activity. Studies that measure participants' existing levels of physical activity or sport participation (including those that compare different levels of physical activity) will not be part of the systematic search, but will be reviewed in the introduction. Interventions that were comprised of a single exercise session, or an exercise that targeted only a single body part (e.g., range of motion exercises for the ankle or wrist) are excluded.

Injury – The study must include the measurement and/or reporting of injuries (or lack thereof) that occurred as a result of participating in physical activity.

Weight – Participants can be in any weight category (underweight, healthy weight, overweight, obese) so that comparisons can be made regarding injury rates across weight categories. There is no requirement that participants' weights are measured or reported by the authors.

Appendix B. Search strategy.

Searches were conducted October 1, 2012.

Databases:

CINAHL (Medline excluded)
EMBASE
ERIC
Medline
PsycINFO

Terms searched in document titles:

activ* or exercis* or sport* or fitness or *weight or obes* or "BMI" or "body mass index"

AND

promot* or intervention* or program* or prescri* or treatment* or therapy or trial* or “RCT”

Limits applied:

Publication date 2005 – 2012
English language
Human populations
Journal Article

Full Text Screening:

Electronic versions of full-text articles were searched using the “find” function in Adobe reader. The following terms were searched for in the following order:

1. Injur
2. Fracture
3. Sprain
4. Strain
5. Adverse

Appendix C. Questions for key informant interviews.

Date:

Organization:

Program:

Name and title of interviewee:

Contact information:

1. Please provide a brief description of the program.
2. Were safety or injury prevention considered as part of the development of the program?
3. Are any safety or injury prevention messages provided to those who participate in the program?
4. Have any evaluations been conducted to determine the benefits of the program in terms of improving physical activity or health?
    a. Are the results of the evaluations available?
    b. Were any data collected on injuries?
5. Do you have any suggestions related to our literature review in terms of what kinds of things we should be looking for?
6. Do you have any suggestions as to other organizations we could contact who are doing any kind of physical activity promotion?
7. Are there any plans to continue with the program in the future?

Appendix D. Description of Evidence Tables

Note the correspondence between the number & order of variables listed in the column header [separated by slashes (/)] & the number of bullets in the cells below.

If the study involves the comparison of 2 or more groups as part of the intervention evaluation, the group that received the physical activity intervention will be identified in bold as **PA** followed by a colon and the characteristics of that group. If more than one group is compared in which physical activity is a component of the intervention, then the groups will be identified as **PA1**, **PA2** etc, with PA1 including the highest intensity of physical activity. Comparison or control interventions that do not include a physical activity component will be identified in bold as **CG** (comparison group) followed by a colon and the characteristics of that group (e.g., **PA**: 52% female; **CG**: 50% female). If no sub-groups are identified, the information refers to the entire sample or the authors did not specify to which group the participants belonged.

Studies that included only overweight/obese participants are presented first, followed by studies that also included participants of healthy weight. Studies are presented in order of research design (randomized controlled trials, quasi-experimental, pre-post, and qualitative), and within each research design by year of publication.

At all times we aim to use language that is consistent with the language used in the report (e.g., to describe different ethnic/religious groups, evaluation results). Furthermore, we only report data that can be retrieved from the main report/documentation, rather than data that are available only from other sources. When information is not reported in the main report, but seems very obvious, the data will be reported following the word "likely."

Study Identification (first column in each table):

- Name of study [Reference Identification Number in brackets]
- Last name of first author, or acronym of organization, who wrote the first published report that describes the study (year of publication of the main report is in brackets)
- Country (or countries) in which the study was conducted

Abbreviations: **UW** = underweight, **HW** = healthy weight (normal or average weight), **OW** = overweight, **OB** = obese, BMI = body mass index, CT = can't tell; NR = not reported in the main report; n/a = not applicable; pt(s) = participant(s); grp(s) = group(s); yr(s) = year(s); mth(s) = month(s); wk(s) = week(s); hr(s) = hour(s); min(s) = minute(s); n = sample size; M = mean (average); SD = standard deviation; Med = median; r = correlation coefficient; S = statistically significant ($p < .05$, unless otherwise specified); NS = not statistically significant ($p > .05$, unless otherwise specified); info = information; diff(s) = difference(s); pop = population; SES = socio-economic status; pos = positive; neg = negative

Baseline = pre-intervention assessment period, **T1** = first assessment period during the physical activity intervention, or first assessment at the end of the intervention, **T2** = second assessment period during the physical activity intervention, **F1** = first follow-up assessment period that took place after the physical activity intervention and after the first assessment period

Evidence Table 1. General study characteristics.

Purpose of study: Explicitly stated purpose or objective of the research described within the report.
Name: Full name of intervention explicitly stated by the authors.
Purpose of intervention: Explicitly stated purpose or objective of the intervention. May or may not involve weight reduction or increasing physical activity (e.g., to increase mobility among seniors; weight reduction among obese children; to encourage employees to be more active)
Intervention type: Manner in which participants were encouraged to engage in physical activity as part of the intervention. SSP = Supervised Specific Prescription in which participants were instructed to engage in a specific type, intensity, and/or duration of physical activity that was supervised by study staff or an exercise trainer, USP = Unsupervised Specific Prescription in which participants were instructed to engage in a specific type, intensity, and/or duration of physical activity that was not supervised by study staff or an exercise trainer, NP = Non-specific Prescription in which participants were encouraged to increase their levels of physical activity but were not given a specific type, frequency or intensity of target exercise.
Weight status: The weight category to which the participants belong. May include participants in more than one weight category. UW = underweight (BMI < 18.5), HW = healthy weight (BMI = 18.5 – 24.9), OW = overweight (BMI = 25-29.9), OB = obese (BMI > 30)
Age group: The age group to which participants belong. Specify early/middle/late when available. Childhood (0-12 years), adolescence (13-18 years), or adulthood (19+)
Research design: Type of research design used to evaluate the effects of the intervention: RCT, quasi-experimental, pre-post, qualitative

Evidence Table 2a: Intervention characteristics.

Setting: The location(s) in which participants engaged in the physical activities that were part of the intervention (e.g., home, playground, gym, research centre).
Instructor characteristics: Any available information about the individuals who implemented the intervention. May include personal characteristics (age, gender), education, training, experience, occupation (e.g., nurses, teachers).
Duration of PA promotion: The total length of time over which participants were instructed or encouraged to engage in physical activity as part of the intervention (e.g., 1 yr).
Type of physical activity: The type of physical activity in which participants were encouraged or instructed to engage as part of the intervention (e.g., walking, swimming). Does not include additional activities in which participants engaged outside of the intervention.

Evidence Table 2b: Intervention characteristics.

Frequency of activity: The frequency with which participants were instructed or encouraged to engage in the physical activities that were part of the intervention (e.g., 3 days/wk).
Length of activity: The length of time participants were instructed or encouraged to engage in the physical activities that were part of the intervention (e.g., 150 min/wk).
Intensity of activity: The target intensity of physical activity that participants was instructed or encouraged as part of the intervention (e.g., moderate).

Table 2c. Intervention characteristics.

Other intervention components: Any characteristics of the intervention other than the physical activity prescription (e.g., diet, counseling, education).
Exercise adherence strategies: Strategies used by the researchers to encourage participation in the intervention and any physical activity (e.g., counseling, mail reminders) that were described by the authors as methods by which to ensure adherence.
Injury prevention strategies: Strategies used to ensure the safety of the participants and/or prevent injuries associated with the physical activity that were part of the intervention, that existed before the intervention, or that were implemented spontaneously by participants or instructors in response to perceived risks associated with the intervention.

Table 3a. Participant characteristics.

Inclusion criteria: Characteristics of individuals that were required in order to be eligible to participate in the study.
Exclusion criteria: Characteristics of individuals that made them ineligible to participate in the study.
Sample size: **Approached**: The number of individuals who were approached or invited to participate in the physical activity intervention. Includes individuals who were approached and screened for eligibility, even if those individuals were found not to be eligible according to inclusion/exclusion criteria.
Sample size: Completed: The number of individuals who completed the intervention and associated assessments, and whose data are included in the statistical analyses.
Reasons for non-participation: Any available information about the reasons that participants who were approached or enrolled in the study did not complete their participation (e.g., refused participation, dropped out, missing data, failed to meet inclusion criteria). The precise numbers or percentages of participants are included when available.

Table 3b. Participant characteristics.

Age: Any available information about the age of the participants, including measures of central tendency (e.g., mean, median) and dispersion (e.g., range, SD).
Gender: Percentage of participants who were female.
SES: Any available information about the socio-economic status of the participants (e.g., education, family income)
Ethnicity: Any available information about the ethnic distribution of participants (e.g., race)
Other relevant characteristics: Any other important characteristics of the participants as a group (e.g., veterans, health conditions, psychiatric disorders)

Evidence Table 3c. Participant characteristics.

Baseline activity: Any available information about the physical activity levels of the participants before starting the intervention (e.g., min/wk, sport participation)
Baseline injuries: Any available information on participants' current or past injuries that were sustained before starting the intervention.
Baseline weight: Any available information about the weight or body composition of the participants (e.g., weight in lbs/kg, BMI, waist circumference, lean/fat mass) before starting the intervention
Baseline health: Any available information about the health of the participants before starting the physical activity intervention (e.g., diseases, smoking, existing injuries).

Evidence Table 4a. Evaluation strategies.

Recruitment strategy: Methods used to recruit individuals to participate in the study.
Group assignment: Methods used to assign participants to various study groups (i.e., intervention vs. control).
Respondent: Individual(s) who completed the assessment (e.g., self-report, teachers, parents, nurses, clinicians). "Measurements" refers to objective measurements of weight, health, physical activity, or other factors that were completed by individuals associated with the research study.

Evidence Table 4b. Evaluation strategies.

Physical activity measurement: **Method**: Methods used to measure participants' actual physical activity levels during the intervention.
Physical activity measurement: Validation: Whether the authors reported information about the process by which the physical activity measurement instruments were validated and/or the reliability or validity of the measurement instruments.
Injury measurement: **Method**: Methods used to measure participants' injuries over the course of the intervention.
Injury measurement: Validation: Whether the authors reported information about the process by which the injury measurement instruments were validated and/or the reliability or validity of the measurement instruments. (Yes/No/Can't Tell)
Timing of assessments: Timing of assessments related to the actual physical activities of the participants, their injuries, weight or body composition, and other health assessments with respect to the baseline assessment (e.g., 3 mo = 3 months after the baseline assessment)

Evidence Table 5a. Outcomes (activity)

Actual Physical Activity: Any available information about the physical activities in which the participants actually engaged as part of the intervention.
Increase in Physical Activity: Any available information, explicitly stated by the authors, about whether the intervention resulted in an increase in physical activity among participants vs. baseline levels.
Rate of Adherence: Rate at which participants engaged in the level of physical activity prescribed as part of the intervention. Must be calculated and explicitly stated by authors.
Extra-Intervention Physical Activity: Any information about physical activities in which the participants engaged that were not part of the intervention.

Evidence Table 5b. Outcomes (injury)

Rate of Injury: The frequency with which participants sustained injuries over the course of the intervention.
Factors Affecting Injury Rates: Factors that were measured as part of the research (other than those specifically related to injury prevention strategies) and found to be significantly associated with injury rates, and factors that were not significantly associated with injury rates (e.g., weight, age, level/type of activity)
Effectiveness of Injury Prevention Strategies: Any available data about whether the injury prevention strategies that were used as part of the intervention had any measureable effect on the actual rate of injury.

Evidence Table 5c. Other outcomes

Weight Loss Outcomes: Changes in weight and/or body composition participants over the course of the intervention.
Health Outcomes: Measured changes in the health of the participants over the course of the intervention, other than weight.
Other relevant outcomes: Relevant outcomes other than those related to weight, injury rates, or health.

Appendix E to Appendix H Available upon request to:

BC Injury Research and Prevention Unit
604.875.3776
bcinjury1@cw.bc.ca