

Do cardiovascular benefits outweigh the potential cardiovascular risks in recreational alpine skiing?

Cardiovascular risk-benefit ratio of alpine skiing in recreational skiers

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Summary

Worldwide, but especially in western countries, there is an epidemic of physical inactivity with its known detrimental health-related effects. Physical activity and regular physical exercise remain difficult to implement especially in sedentary elderly subjects, often because of a lack of appealing physical activities. Gaining the attraction of these target groups is a prerequisite in order to improve adherence. Alpine skiing is performed by millions of recreational subjects in the Alps alone and may be an attractive mode of physical activity for many local citizens and tourists alike. Besides the well-known positive effects of exercise on cardiovascular and other health-related outcomes, the risks also need to be considered. Indeed, myocardial infarction and sudden cardiac death during alpine skiing in recreational skiers are the leading causes of death in the Alps during the winter and exceed the number of fatalities due to avalanches or traumatic deaths. It is the aim of this article to provide an up-to-date evaluation of the potential cardiovascular risks of recreational alpine skiing as well as the known benefits thereof. In the first section a general cardiovascular risk-benefit evaluation of physical activity is provided. Thereafter the current knowledge of the cardiovascular benefits and risks of alpine skiing are summarized, followed by a discussion and conclusion.

Key words: downhill skiing; sudden cardiac death; myocardial infarction; cardiovascular risk; physical activity

Introduction

Alpine skiing represents one of the most popular winter sports worldwide and particularly in Alpine regions. Annually, an estimated 8 million skiers visit the mountainous regions of Austria alone [1]. Although alpine skiing is performed professionally by many athletes, the vast majority of people on skiing slopes are recreational skiers, tourists and residents of a given skiing area.

Unfortunately, in recent years, a number of tragic skiing accidents have occurred in prominent professional and recreational skiers: Prince Friso of Orange-Nassau, Michael Schumacher, Dieter Altaus, Matthias Lanzinger, Ulrike Maier, Daniel Albrecht, Hermann Maier,

Arnold Schwarzenegger and Hans Grugger, to name a few. Partly because of the media coverage, the public perception of the major risk of death or injury during alpine skiing are traumatic events. However, a recent evaluation in Austria analysed all traumatic and non-traumatic fatal ski accidents from the 2005–2006 to the 2009–2010 winter season in Austria. In total, 207 fatalities were registered during this time period, 52.7% were nontraumatic deaths, with the majority (73%) attributed to cardiac arrests [2]. Consequently, parallel to the efforts to prevent traumatic deaths and injuries in professional and recreational skiing [3], prevention of nontraumatic events such as myocardial infarction or sudden cardiac death are warranted.

Regular physical activity, including recreational alpine skiing, is known to positively modulate cardiovascular risk factors and subsequently the risk of cardiovascular events. Therefore, alpine skiing as part of an active lifestyle may contribute to cardiovascular health and longevity. The traumatic risks and the potential measures to prevent them have been discussed in detail elsewhere [3].

It was the aim of this article to provide an up-to-date evaluation of the potential cardiovascular risks of recreational alpine skiing as well as the known benefits thereof. In the first section a general cardiovascular risk-benefit evaluation of physical activity is provided. Thereafter the current knowledge of the cardiovascular benefits and risks of alpine skiing are summarised, followed by a discussion and conclusion.

Risk-benefit evaluation of physical activity in general

Benefits of physical activity/exercise

Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure, whereas physical exercise is physical activity aimed to improve or maintain physical fitness. Physical inactivity is defined as the absence of a minimum physical activity. Particularly in developed

countries, physical inactivity is a major health burden. Evidence clearly demonstrates beneficial effects of physical activity on cardiovascular disease and all-cause mortality [4]. Approximately 20% of the adult population worldwide is physically inactive [5], and this condition is particularly prevalent in women, the elderly and in persons with low socioeconomic status. Additionally, the percentage of time spent on sedentary behaviour, specifically watching television or in front of a computer (i.e., screen time), is increasing [6]. Large prospective cohort studies from several countries around the world have found that sedentary behaviour is associated with a variety of poor health outcomes, including increased mortality [7, 8]. One study calculated the attributable risk for premature mortality and estimated that physical inactivity worldwide causes 9% of premature mortality, accounting for 5.3 million deaths worldwide in 2008 [8], which is on par with death caused by cigarette smoke. A 10% reduction in physical inactivity could prevent 533 000 deaths every year. Regular physical activity and higher cardiorespiratory fitness decrease overall mortality in a dose-response fashion [4, 9].

Physical exercise affects multiple systems and health outcomes. A dose-dependent relationship between exercise and the development of common chronic conditions such as cardiovascular disease, diabetes mellitus, chronic obstructive pulmonary disease, chronic kidney disease, Alzheimer's disease and some cancers has been observed [10]. The evidence of health benefits of physical activity on mortality mostly stems from observational trials, which suggest that regular exercise reduces risk of all-cause mortality for most individuals, including younger and older men and women in a dose-dependent manner [4, 11, 12].

A number of studies have shown a strong inverse relationship between habitual exercise and risk of cardiovascular disease: coronary disease, cardiac events, stroke and cardiovascular death for both primary and secondary prevention [4, 13–16]. Furthermore, exercise training beneficially alters levels of markers of inflammation (C-reactive protein and interleukin-6) [17], systemic blood pressure [18], blood lipids, body composition and thrombogenic risk. With respect to diabetes, exercise training improves glycaemic control, insulin sensitivity and may prevent the development of type 2 diabetes in high-risk groups [18, 19].

In a number of observational studies, physical activity and/or regular exercise were shown to protect against breast, intestinal, prostate, endometrial and pancreatic cancer [20, 21]. Exercise was also shown to positively affect fatigue and quality of life for survivors of breast, colorectal and prostate cancers. Furthermore, exercise

training was shown to counteract obesity [18, 22, 23], osteoporosis, stress, anxiety and depression [24–26]. Regular exercise training may also increase the likelihood of stopping tobacco use, reduce disability for activities of daily living in older persons and delay cognitive decline in older adults.

Possible risks of physical activity/exercise

The benefits of physical activity far outweigh the possible associated risks in the majority of patients in the absence of a contraindication to exercise. However, as in every therapeutic intervention, side effects need to be considered.

Musculoskeletal injury is the most common risk of exercise [27, 28]. Although studies indicate that those who engage in sports activities have a higher risk of minor injury, people who do not participate in sports or other physical activity on a regular basis are more likely to incur more severe injuries when engaging in such activities [29]. Many of the musculoskeletal injuries are secondary to overuse [30] and may be prevented by adequate training methods.

More serious but much less common risks include traumatic death mostly due to traumatic brain injury, traumatic injury of the neck, or traumatic chest trauma including commotio cordis, arrhythmia, sudden cardiac death and myocardial infarction.

Serious and catastrophic traumatic events in sports are rare, and vary between sporting disciplines, gender, age and skill level [31]. In a recent report, a state-of-the-art overview on the epidemiology and clinical decision making in major injuries during sporting activities of head, neck, chest and abdomen has been provided [31]. The risk of arrhythmia during exercise in patients with underlying heart disease or with a prior history of arrhythmia is increased. Exercise training may reduce atrial and ventricular arrhythmia risk by increasing myocardial oxygen supply and by reducing sympathetic nervous system activity. Sudden cardiac death (SCD) is rare, but may occur during physical or sexual activity [32]. The increase in risk is seen in both men and women; however, the risk of cardiac arrest is reduced or may not be increased at all if the subjects are engaged in habitual leisure-time physical activity, as studied in both the Physicians' Health Study and the Nurses' Health Study [33, 34]. Mechanisms of SCD in those who exercise include coronary artery disease, arrhythmias (especially ventricular tachycardia and ventricular fibrillation), structural heart disease and myocarditis. Causes of SCD in people who exercise can be divided according to age [35]. SCD is generally a re-

sult of atherosclerotic coronary artery disease in those over 35 years of age. It is more likely to be due to congenital abnormalities such as hypertrophic cardiomyopathy, right ventricular arrhythmogenic dysplasia/cardiomyopathy, coronary anomalies or to myocarditis in younger individuals. As the increase in risk of SCD during or just after activity is low, the long-term health benefits of exercise outweigh the risks in patients with and without established heart disease [36–38].

Physical or sexual activity is associated with a temporary increase in the risk of having a myocardial infarction (MI), particularly among males [39] who exercise infrequently and have multiple cardiac risk factors [32, 36].

Although patients with coronary disease are more likely to have a myocardial infarction at the time they are participating in strenuous exercise than when they are not, patients with coronary disease who exercise are overall less likely to have a myocardial infarction than those with coronary disease who do not exercise [40].

Rhabdomyolysis (i.e., subclinical myoglobinaemia, myoglobinuria, and elevation of creatine kinase) is common after physical exertion [41]. The creatine kinase level can rise several fold, particularly after intense exercise for extended periods of time (e.g., marathon running). Rhabdomyolysis may occur following extreme exertion in individuals with normal muscles when the energy supply to the muscle is insufficient to meet demands. Rare and severe complications of rhabdomyolysis after intense prolonged exercise (often in untrained individuals, hot and humid conditions, impaired thermoregulation, underlying disease) include renal failure, electrolyte abnormalities such as hyperkalaemia, and metabolic acidosis and compartment syndrome. However, rhabdomyolysis can also occur in trained individuals following physical exertion in the absence of these risk factors.

Other potential risks of exercise especially in winter sports and at altitude comprise exercise-induced bronchoconstriction in patients with current symptomatic asthma [42], hyperthermia, hypothermia and dehydration. In women, intense exercise may lead to the “female athlete triad” which consists of eating disorders, amenorrhoea and osteoporosis. Also, urticaria and anaphylaxis can occasionally occur with exercise, especially in combination with ingestion of certain foods. Finally, exercise-associated hyponatraemia has been reported in long-lasting endurance sports. Medical evaluation prior to initiation of an exercise programme focuses on risks for coronary heart disease and other potential medical comorbidities that might

place the patient at risk for one of the complications above.

It would be beyond the scope of this article to discuss the role of screening of individuals who are exposed to the potential risks of exercise: patients, healthy subjects and athletes alike. Although a lively scientific debate [43, 44] is ongoing about risks and benefits of screening prior to exercise, it is the opinion of the authors that screening should be performed in the majority of subjects and should include a 12-lead resting electrocardiogram (ECG). Also, measures of injury prevention should be performed in order to identify subjects at risk of injury and to recommend adequate sporting disciplines, as well as exercise characteristics such as intensity and frequency. Despite the benefits of an exercise programme, there are risks as noted above, even in trained athletes. As a result, the American Heart Association (AHA) has published a summary outlining the absolute and relative contraindications for exercise testing and training. The absolute contraindications include severe cardiac disease (e.g., unstable angina, uncontrolled symptomatic heart failure) and acute noncardiac disease (e.g., infection, renal failure). Recommendations for injury prevention should be tailored to specific populations. As an example, older populations may be at risk of falls. As the older population may get injured more easily and recover more slowly, some patients will benefit from supervised exercise. Generally, warm-up and cool-down is recommended in all exercising populations. Supervision and/or counselling seem to be beneficial [45], as many subjects and patients show poor adherence to exercise recommendations. However, the effectiveness of counselling has not been demonstrated.

It is recommended that all healthy adults incorporate moderate to vigorous exercise into their lifestyle. One option is moderate intensity exercise for 150 minutes per week, vigorous intensity exercise for 75 minutes per week, or an equivalent combination of these activities. Adults with limited exercise capacity due to comorbidity should stay as physically active as their condition allows. Even modest increases in exercise are associated with health benefits.

Benefits of alpine skiing – summary of current knowledge

The physiological effects and potential health benefits of alpine skiing have only been sparsely studied. While alpine skiing as a leisure-time physical activity has become increasingly popular, most of the sports medicine literature has focused on frequency, prevention and treatment of alpine skiing injuries. To our knowl-

edge the potential metabolic and cardiovascular benefits of alpine skiing in a recreational population have so far been studied in only three studies [46–60]. A brief summary of these three studies are listed in table 1.

The first study, by Kahn et al., which aimed to investigate cardiovascular effects of alpine skiing, was a small (n = 10, 100% males, age 51.0±1.3 years) uncontrolled Swiss investigation that measured the effects of 6 days of unsupervised alpine skiing. The participants were habitually sedentary. Heart rate was recorded during skiing and was 126 beats min⁻¹ on average, which corresponds to 75% of a calculated (220–age[years]) maximal heart rate. The main finding was a significant improvement of insulin resistance and a significant increase in apolipoprotein A1 / apolipoprotein A2 (p <0.01) [59]. The authors reported no injuries or cardiovascular events. A second study set out to investigate the effects of alpine skiing in an elderly population, the Salzburg Skiing for Elderly Study (SASES) [58]. The aim of this study was to monitor the long-term effects of skiing on health-related parameters of older individuals. This randomised controlled study was performed in an intervention group (n = 22, age 67.5±2.8 years, 12 males / 10 females) and a control group (n = 20, age 67.3±4.4 years, 10 males / 10 females). Parameters of interest were measured during pre-, post- and retention-tests (10 weeks after “post” measurements). The intervention phase lasted for 12 weeks, with an average of 28.5 days of guided skiing. Daily heart rate profiles and global positioning system data throughout the ski day were recorded. The intervention group completed an average of 4885 vertical metres of downhill skiing

daily, with a total skiing distance of 40.5 km/day. During skiing, the average heart rate was 72.4 ± 8.9% of the maximal heart rate measured at maximal exertion during spiroergometry. Strength measured by jump height increased in the intervention group, while jump height for the control group deteriorated. Dynamic maximal strength measured in both legs increased in the intervention group, however, did not reach statistical significance in the control group. In postural ability, no differences between groups or over time were noted. Several morphological and structural adaptations of musculature and tendons, as well as postural control, were observed, indicating that alpine skiing may be an effective intervention for combating sarcopenia, frailty and weakness in old age. The effects of 12 weeks of guided alpine skiing training on psychosocial dimensions and physical self-concept were also observed.

With respect to cardiovascular risk factors the authors observed a significant increase in exercise capacity in the intervention group (ΔV_{O_2max} : +2.0 ml/kg/min, p = 0.005) but not in the control group (ΔV_{O_2max} : -0.1 ml/kg/min, p = 0.858; IG vs CG: p = 0.008). Also, a decrease in body fat mass (IG -2.3%, p <0.0001; CG ±0.0%, p = 0.866; IG vs CG p <0.0001) was achieved. Blood pressure, blood lipids, heart rate and everyday physical activity remained essentially unchanged. Furthermore, cardiovascular biomarkers were addressed without relevant changes except for homocysteine. Alpine skiing also affected parameters of copper status. This finding is of relevance, since an imbalance of copper has been associated with cardiovascular risk. Finally, an improvement of glucose homeostasis and insulin

Table 1: Brief summary of the three studies that investigated the cardiovascular effects of recreational alpine skiing.

First author and year of publication	Type of intervention	Participants	Intervention	Cardiovascular outcomes
Kahn 1996	Uncontrolled pre-post study	n = 10, 100% males, age 51.0±1.3 years	Uncontrolled, 6 days of unsupervised alpine skiing	Improvement of insulin resistance; increase in apolipoprotein A1 / apolipoprotein A2
Dela 2011 and Niederseer 2011 SASES Study	Randomised controlled study	Intervention group (n = 22, age 67.5±2.8 years, 12 males / 10 females) control group (n = 20, age 67.3±4.4 years, 10 males / 10 females)	Intervention group: 12 weeks, with an average of 28.5 days of guided skiing; or control group: sedentary lifestyle without alpine skiing	Improvement of body composition; Improvement in insulin resistance; Blood pressure, blood lipids, heart rate and everyday physical activity remained essentially unchanged; Cardiovascular biomarkers did not change except for homocysteine Positive effects on copper metabolism
Burtscher 2013	Questionnaire-based cohort study	1 259 long-term downhill skiers (971 males, aged 57.3±14.6 years; 288 females, aged 47.7±16.4 years)	Lifetime skiing vs general population	Long-term alpine skiing on a regular basis may contribute to healthy aging by its association with a healthier life style; positive effects on cardiovascular risk factors (hypercholesterolaemia, diabetes mellitus type 2) and memory complaints

sensitivity in the nondiabetic elderly skiers was observed.

A third study by Burtscher et al. aimed to compare lifestyle characteristics and cardiovascular risk factors between regular downhill skiers and the general population. They investigated self-reported health and lifestyle data, including memory function, which were obtained via questionnaire from 1259 long-term downhill skiers (971 males, aged 57.3 ± 14.6 yrs; 288 females, aged 47.7 ± 16.4 yrs) and compared the findings with data from the general population. Long-term skiers showed more favourable lifestyle characteristics and a better health status than the general population. Although skiers reported a healthier lifestyle with respect to regular aerobic exercise, less smoking, and less alcohol consumption in comparison with the general population, the prevalence of cardiovascular risk factors such as hypercholesterolaemia, arterial hypertension and diabetes did not differ between the two populations. Thus, the authors concluded that the healthier lifestyle of downhill skiers did not seem to translate into a reduced prevalence of cardiovascular risk factors. However, the prevalence of these risk factors decreased with increasing annual skiing frequency and therefore the findings indicate a significant “dose-dependent” effect of downhill skiing on self-reported cardiovascular risk factors and memory deficits. Differences observed between male and female skiers were similar to the gender differences demonstrated for the general population and may at least partly be explained by age effects in that study. The authors pointed out that it was not only downhill skiing activities which may have contributed to the demonstrated beneficial effects but rather the generally healthier lifestyle associated with long-term regular downhill skiing. Nevertheless, the increasing yearly skiing frequency was an independent predictor for the reduced prevalence of hypercholesterolemia, diabetes type 2 and memory complaints. In conclusion, long-term alpine skiing on a regular basis may contribute to healthy aging by its association with a healthier lifestyle.

Risks of alpine skiing – summary of current knowledge

In a study by Ruedl et al. (already mentioned in the introduction) nontraumatic and traumatic causes of death on Austrian ski slopes were evaluated from the 2005–2006 to the 2009–2010 winter season [2]. In total, 207 fatalities were registered during this time period. An overall incidence of 0.79 deaths per million skier days was calculated. Mean age at death was 50.9 ± 17.7 years. More than 85% of all fatalities occurred in males

and 93.1% in skiers. In total, 52.7% were nontraumatic deaths, with the majority (73%) attributed to cardiac arrest. Regarding traumatic deaths, 41.2% died after a fall, 18.6% after collision with another skier, and 35.1% after an impact with a solid object. Head injury was the primary cause of death in 46.4% of traumatic deaths.

As stated above the major cause of injuries during exercise are musculoskeletal injuries. The number of injuries during alpine skiing has decreased over the last 50 years: before 1970, 7–8 injuries; during the 1980s, 3–4; during the 1990s, 2–3; since 2000 $\leq 2/1000$ skiing days. In a recent report about skiing injuries in Austria the calculated injury rate was 0.6 injuries per 1000 skier days and has decreased by more than 50% during the past decade [61].

In the SASES study, the skiing intervention proved to be safe. There were no cardiovascular events. However, two serious injuries occurred during the 12-week skiing intervention (a fracture of the proximal humerus and a fracture of the tibia plateau). Nevertheless, only one of these injuries occurred during actual skiing. The humerus fracture was the unfortunate result of a sideways fall from a standing position because of a balance impairment. The tibia plateau fracture occurred at the end of a turn when the skier tried to stop and lost his balance. This resulted in an injury rate of 3.2 per 1000 skiing days. However, this rate must be evaluated with considerable reservations and cannot easily be compared to other studies, because the skiing intervention consisted of only 627 skier days. In larger studies, consisting of 1.2 million skier days, an injury rate in recreational skiing was found to be 1.3 per 1000 skiing days [62]. Apart from the two fractures, three other subjects terminated their participation in the study because of exacerbation of old injuries (knee pain). In retrospect, these three subjects should probably have been excluded already in the screening procedure. A detailed evaluation of the traumatic risks of alpine skiing is provided elsewhere [3].

With respect to cardiovascular risks during alpine skiing, myocardial infarction and sudden cardiac death are addressed. To our knowledge no case of sudden cardiac death or myocardial infarction of a professional athlete in alpine skiing has been published.

Myocardial infarction

In a retrospective analysis of consecutive patients admitted to the Department of Cardiology at Innsbruck Medical University, Austria, with the diagnosis of an acute myocardial infarction, Klug et al. [63] analysed 110 patients (non-Austrian tourists, mean age 60 ± 10 years, 16% women, 71% ST-elevation myocardial infarc-

tion, 23% known coronary artery disease) retrospectively in the Tyrolean Alps in 2006–2010. During the first 2 days of physical activity, 56% of acute myocardial infarctions occurred. In tourists who suffered acute myocardial infarction during or within 1 hour after cessation of activity (52%), the mean time from the start of the activity to the onset of symptoms was 2.0 ± 1.7 h. In total, 56% of patients performed less than 2.5 h of sport per week before their holidays and may therefore be considered as untrained. Also, 70% had ≥ 2 cardiovascular risk factors. Less than 18% of the 93 events occurred after day 4 of skiing [64].

A French prospective registry investigated the management and outcomes of ST-segment elevation myocardial infarction (STEMI) in the French Alps between January 2006 and December 2008. In summary, the authors reported 114 patients with a STEMI of less than 12 hours duration, occurring in a ski resort or at high altitude and managed by the RESURCOR care system. A total of 93% of patients were men; the mean age was 57 years. STEMI occurred during or less than 1 hour after physical activity in 76.3% of cases (42.1% during or after alpine skiing). Killip class ≥ 2 and cardiac arrests were observed in 35 and 7.9% of cases, respectively. A total of 52 (45.6%) patients underwent thrombolysis and 62 (54.4%) had a percutaneous coronary intervention (PCI). Median delays were: first call to treatment, 82 min (17–230 min); symptoms to treatment, 165 min

(52–770 min). All delays were significantly longer for PCI than for thrombolysis. First call to treatment delay was less than 120 min in 98.1% of patients who underwent thrombolysis and in 51.6% who had percutaneous coronary intervention ($p < 0.0001$). In-hospital survival was 96.5%. Chacornac et al. concluded that altitude STEMI happened mainly during sporting activities, especially alpine skiing, in the investigated region. Clinical presentation was often severe, but an emergency coronary care network allowed rapid reperfusion [65].

Interestingly, the geographic variations between the French and the Austrian Alps highlight the difference in the initial revascularisation strategy. Whereas in France, thrombolysis and PCI were almost balanced, not one of the reported Austrian STEMI patients was treated with thrombolysis, presumably because of geographical differences and consequently faster access to percutaneous coronary intervention facilities.

Sudden cardiac death

It has been discussed extensively whether physical exertion is not only a means of decreasing cardiovascular risk, but rather a risk factor for sudden cardiac death itself. This is true for summer sports such as marathon running [66] but also for mountain sports. Burtcher and Ponchia [67] report an annual death rate of 0.76 per

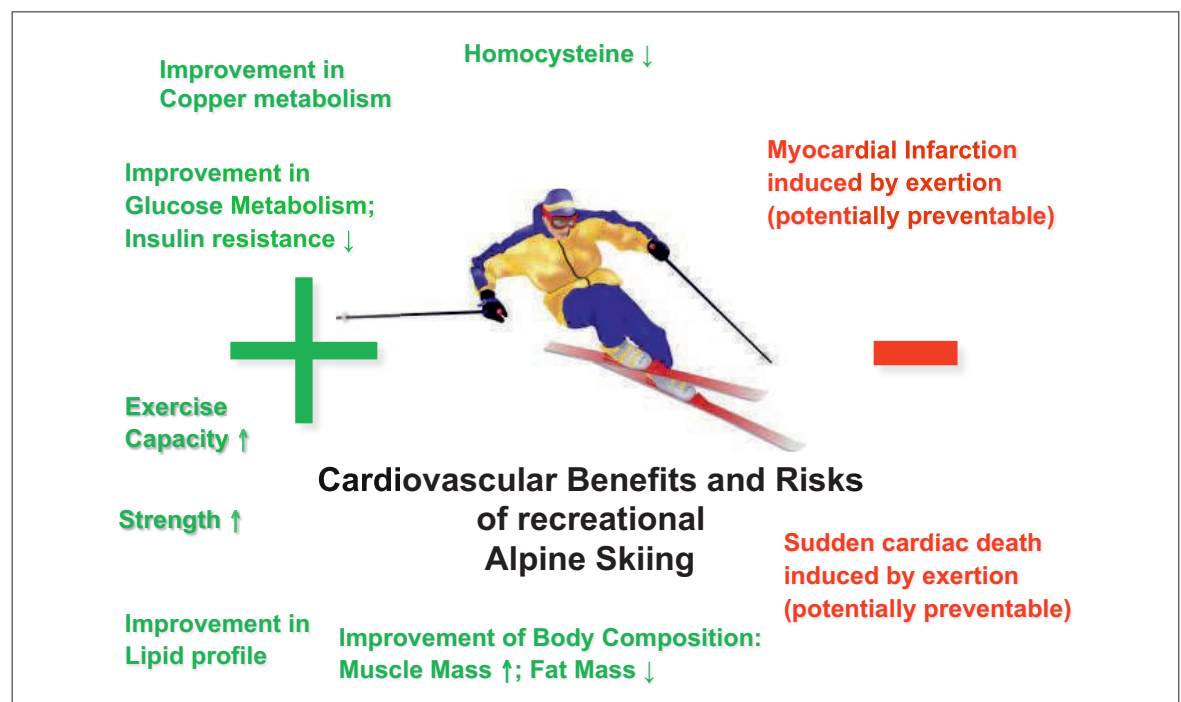


Figure 1: Overview of cardiovascular benefits and risks of recreational alpine skiing.

100 000 persons in alpine skiers in the Austrian Alps (up to approximately 3800 m above sea level). About 25% of all deaths were attributed to the cardiac system. The frequencies of cardiac causes of death were particularly high in mountain sports preferred by the elderly, such as alpine skiing [68]. About 43% of alpine skiers in the Austrian Alps are older than 40 years and 15.3 to 28.0% of those had pre-existing cardiovascular diseases [69]. As a result, the risk of cardiovascular events during skiing in the mountains increases sharply with age. Male skiers older than 35 years comprised about 90% of all deaths [67].

In a detailed analysis of sudden cardiac deaths in downhill skiing, Burtscher et al. [1] evaluated the risk factor profiles of 68 males who died from sudden cardiac death during downhill skiing and compared them with those of 204 matched controls. Skiers who suffered sudden cardiac death had prior myocardial infarction more frequently (41 vs 1.5%; $p < 0.001$), hypertension (50 vs 17%; $p < 0.001$), known coronary heart disease without prior myocardial infarction (9 vs 3%; $p = 0.05$) and were less engaged in strenuous exercise (4 vs 15%; $p < 0.05$) than controls. Multivariate analyses underscored the importance of these risk factors. In figure 1, the cardiovascular benefits and risks of alpine skiing are summarised.

Discussion

Current literature clearly indicates that alpine skiing is safe and beneficial and can also be recommended to the elderly. Like in other training interventions, preventive measures such as starting slowly on the first days or being optimally treated with respect to the risk profile is warranted, so that alpine skiing can unfold its huge potential on altering the cardiovascular risk profile. Nevertheless, as with other sports, elderly subjects should undergo an annual cardiovascular check-up, which should at least include a 12-lead ECG and, even better, a maximal ergometry in order to reduce the risk of exercise-induced cardiovascular events. Indeed, during the run-in phase of the SASES study, stress testing revealed a ST-segment depression in one of the subjects, requiring coronary angiography and subsequent coronary artery bypass graft [70]. Overall, the data support a potentially important role of skiing as part of a year-round exercise programme that contributes to a reduction in cardiovascular risk. Former or current elderly skiers may very well be encouraged to continue with or to revive their skiing practice. As shown in the study of Burtscher et al. [46], skiing reveals its potential benefits in a dose-dependent fashion also after decades of regular skiing.

The study by Klug et al. [63] sheds light on the possible mechanism of cardiovascular events during skiing, namely that relatively untrained subjects do too much in their skiing holidays within the first days. As in all sports, elderly subjects are advised to undergo an annual physical check-up in order to detect and treat cardiovascular risk factors. ECG-based ergometry prior to skiing might prevent the majority of cardiovascular casualties. Furthermore, the physician can give informed advice to start slowly with skiing. Faulhaber et al. [71] conducted a survey on the prevalence of cardiovascular diseases such as coronary artery disease with and without prior myocardial infarction, arterial hypertension, and arrhythmias in a representative sample of 1043 alpine skiers in the Austrian Alps. A total of 11.2% (9.3 to 13.1) of the skiers suffered from at least one type of cardiovascular disease. The frequency of cardiovascular diseases is age-dependent and more pronounced in men, the group known to represent the vast majority of fatalities. Skiing-related increased sympathetic activity might well disturb the autonomic balance with subsequent arrhythmias and/or may increase cardiac work and platelet aggregability with possible plaque rupture and coronary thrombosis. Therefore, adaptation to high-intensity exercise and therapeutic interventions or abstinence from skiing in certain cases should be considered for downhill skiers at high risk.

Numerous studies have reported an age-dependent decline of $VO_2\text{max}$ of about 10% per decade. Other studies have proved the hypothesis that physically active subjects suffer a decline of only about 5% per decade [72]. Myers et al. [73] reported 1256 deaths of 6213 veterans who underwent routine exercise testing during a follow-up period of 6.2 ± 3.7 years and found that exercise capacity was the strongest independent predictor of all cause-mortality in these subjects, even stronger than the well-established risk factors such as smoking, arterial hypertension, dyslipidaemia or diabetes. Given this fact, the result of significant improvement of $VO_2\text{max}$ in the skiing group of the SASES study ($+2.0 \pm 2.0$ ml/kg/min; $p = 0.005$) suggests a substantial reduction in the overall cardiovascular risk. This change corresponds well with other studies in older subjects, although exercise training other than skiing was performed ($+2.0$ ml/kg/min; $p < 0.0001$ [74] or $+3.0$ ml/kg/min; $p < 0.001$ [75]).

The average body composition of elderly Caucasians is slightly different in males and females. Several longitudinal and cross-sectional studies investigated the average fat mass of certain ages and taken together these studies indicate an increase in fat mass of about 1% of the body mass per decade [76]. As fat is a highly

metabolic tissue also involved in the pathogenesis of atherosclerosis [77], a reduction of fat mass, mainly visceral fat, is associated with a reduction of cardiovascular risk. In the SASES study fat mass decreased by -2.3% ($p < 0.0001$) in skiers and remained unchanged in the control group ($\pm 0.0\%$ [$p = 0.866$]; IG vs CG: $p < 0.0001$). As total weight and therefore body mass index (BMI) remained essentially unchanged, an increase in fat-free mass could be achieved, namely muscle mass. Given an age-dependent decline of muscle mass and an increase of fat mass accompanied by a further increase in total weight in most of the elderly, a 2% reduction of the fat/muscle ratio is quite impressive. Other training studies report a similar effect on body composition with other interventions such as strength training or ergometer-based endurance training [78].

It is of interest to patients who suffer from arterial hypertension, how blood pressure changes during alpine skiing. Krautgasser et al. [79] studied six healthy subjects (mean age: 61.2 ± 4.6 yrs; BMI: 26.9 ± 5.0) in a laboratory and during 30 and 75 min of recreational downhill skiing. There was no difference for diastolic blood pressure between field and laboratory tests; however, systolic blood pressure increased after 30 min of skiing to 171 ± 20 ($p < 0.009$) and 165 ± 17 ($p < 0.003$) after 75 min. These values remained below the mean peak systolic blood pressure determined in laboratory tests (218 ± 31). The authors conclude that no dramatic blood pressure peaks are achieved during recreational skiing.

Alpine skiing and ski training include elements of both endurance and of strength training and both result in

beneficial metabolic effects. Besides the cardiovascular effects, the muscular changes as well as the changes in tendon on presumably bone density remain of utmost importance for elderly subjects in order to counteract frailty, falls and sarcopenia with all its related problems.

Conclusion

In conclusion, it is the opinion of the authors that the cardiovascular benefits far outweigh the potential cardiovascular risks in recreational alpine skiing. However, the possibility of serious adverse events is real and should be counteracted by adequate screening and, if necessary, preventive action prior to starting alpine skiing. Overall, the reported data support an important role of alpine skiing as part of a year-round exercise programme which largely contributes to a reduction in cardiovascular risk. Former or current elderly skiers may very well be encouraged to revive or to continue with their skiing practice.

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References

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References

- Burtscher M, Pachinger O, Mittleman MA, Ulmer H. Prior myocardial infarction is the major risk factor associated with sudden cardiac death during downhill skiing. *International journal of sports medicine*. 2000;21(8):613-5.
- Ruedl G, Bilek H, Ebner H, Gabl K, Kopp M, Burtscher M. Fatalities on Austrian ski slopes during a 5-year period. *Wilderness & environmental medicine*. 2011;22(4):326-8.
- Hebert-Losier K, Holmberg HC. What are the exercise-based injury prevention recommendations for recreational alpine skiing and snowboarding? A systematic review. *Sports medicine (Auckland, NZ)*. 2013;43(5):355-66.
- Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. *JAMA : the journal of the American Medical Association*. 2009;301(19):2024-35.
- Dumith SC, Hallal PC, Reis RS, Kohl HW, 3rd. Worldwide prevalence of physical inactivity and its association with human development index in 76 countries. *Preventive medicine*. 2011;53(1-2):24-8.
- Rey-Lopez JP, Vicente-Rodriguez G, Ortega FB, Ruiz JR, Martinez-Gomez D, De Henauw S, et al. Sedentary patterns and media availability in European adolescents: The HELENA study. *Preventive medicine*. 2010;51(1):50-5.
- Proper KI, Singh AS, van Mechelen W, Chinapaw MJ. Sedentary behaviors and health outcomes among adults: a systematic review of prospective studies. *American journal of preventive medicine*. 2011;40(2):174-82.
- Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet*. 2012;380(9838):219-29.
- Gupta S, Rohatgi A, Ayers CR, Willis BL, Haskell WL, Khera A, et al. Cardiorespiratory fitness and classification of risk of cardiovascular disease mortality. *Circulation*. 2011;123(13):1377-83.
- Willis BL, Gao A, Leonard D, Defina LF, Berry JD. Midlife fitness and the development of chronic conditions in later life. *Archives of internal medicine*. 2012;172(17):1333-40.
- Paffenbarger RS, Jr., Hyde RT, Wing AL, Lee IM, Jung DL, Kampert JB. The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. *The New England journal of medicine*. 1993;328(8):538-45.
- Leitzmann MF, Park Y, Blair A, Ballard-Barbash R, Mouw T, Hollenbeck AR, et al. Physical activity recommendations and decreased risk of mortality. *Archives of internal medicine*. 2007;167(22):2453-60.
- Wessel TR, Arant CB, Olson MB, Johnson BD, Reis SE, Sharaf BL, et al. Relationship of physical fitness vs body mass index with coronary artery disease and cardiovascular events in women. *JAMA : the journal of the American Medical Association*. 2004;292(10):1179-87.
- Myers J, Kaykha A, George S, Abella J, Zaheer N, Lear S, et al. Fitness versus physical activity patterns in predicting mortality in men. *The American journal of medicine*. 2004;117(12):912-8.
- Yusuf S, Hawken S, Ounpuu S, Dans T, Avezum A, Lanas F, et al. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. *Lancet*. 2004;364(9438):937-52.
- Wendel-Vos GC, Schuit AJ, Feskens EJ, Boshuizen HC, Verschuren WM, Saris WH, et al. Physical activity and stroke. A meta-analysis of observational data. *International journal of epidemiology*. 2004;33(4):787-98.
- Hamer M, Sabia S, Batty GD, Shipley MJ, Tabak AG, Singh-Manoux A, et al. Physical activity and inflammatory markers over 10 years: follow-up in men and women from the Whitehall II cohort study. *Circulation*. 2012;126(8):928-33.
- Strasser B, Siebert U, Schobersberger W. Resistance training in the treatment of the metabolic syndrome: a systematic review and meta-analysis of the effect of resistance training on metabolic clustering in patients with abnormal glucose metabolism. *Sports medicine (Auckland, NZ)*. 2010;40(5):397-415.
- Tuomilehto J, Lindstrom J, Eriksson JG, Valle TT, Hamalainen H, Ilanne-Parikka P, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *The New England journal of medicine*. 2001;344(18):1343-50.
- Michaud DS, Giovannucci E, Willett WC, Colditz GA, Stampfer MJ, Fuchs CS. Physical activity, obesity, height, and the risk of pancreatic cancer. *JAMA : the journal of the American Medical Association*. 2001;286(8):921-9.
- Kushi LH, Doyle C, McCullough M, Rock CL, Demark-Wahnefried W, Bandera EV, et al. American Cancer Society Guidelines on nutrition and physical activity for cancer prevention: reducing the risk of cancer with healthy food choices and physical activity. *CA: a cancer journal for clinicians*. 2012;62(1):30-67.
- Irwin ML, Yasui Y, Ulrich CM, Bowen D, Rudolph RE, Schwartz RS, et al. Effect of exercise on total and intra-abdominal body fat in postmenopausal women: a randomized controlled trial. *JAMA : the journal of the American Medical Association*. 2003;289(3):323-30.
- Slentz CA, Duscha BD, Johnson JL, Ketchum K, Aiken LB, Samsa GP, et al. Effects of the amount of exercise on body weight, body composition, and measures of central obesity: STRRIDE—a randomized controlled study. *Archives of internal medicine*. 2004;164(1):31-9.
- Herring MP, O'Connor PJ, Dishman RK. The effect of exercise training on anxiety symptoms among patients: a systematic review. *Archives of internal medicine*. 2010;170(4):321-31.
- Neunhauserer D, Sturm J, Baumgartlinger MM, Niederseer D, Ledl-Kurkowski E, Steidle E, et al. Hiking in Suicidal Patients: Neutral Effects on Markers of Suicidality. *The American journal of medicine*. 2013.
- Sturm J, Ploderl M, Fartacek C, Kralovec K, Neunhauserer D, Niederseer D, et al. Physical exercise through mountain hiking in high-risk suicide patients. A randomized crossover trial. *Acta psychiatrica Scandinavica*. 2012;126(6):467-75.
- Falvey EC, Eustace J, Whelan B, Molloy MS, Cusack SP, Shanahan F, et al. Sport and recreation-related injuries and fracture occurrence among emergency department attendees: implications for exercise prescription and injury prevention. *Emergency medicine journal : EMJ*. 2009;26(8):590-5.
- Conn JM, Annett JL, Gilchrist J. Sports and recreation related injury episodes in the US population, 1997-99. *Injury prevention : journal of the International Society for Child and Adolescent Injury Prevention*. 2003;9(2):117-23.
- Diener-Martin E, Bruegger O, Martin B. Physical activity promotion and safety prevention: what is the relationship in different population groups? *British journal of sports medicine*. 2011;45(4):332-3.
- Wen DY. Risk factors for overuse injuries in runners. *Current sports medicine reports*. 2007;6(5):307-13.
- Gammons M. Evaluation and treatment of trauma related collapse in athletes. *Current reviews in musculoskeletal medicine*. 2014.

32. Dahabreh IJ, Paulus JK. Association of episodic physical and sexual activity with triggering of acute cardiac events: systematic review and meta-analysis. *JAMA : the journal of the American Medical Association*. 2011;305(12):1225-33.
33. Albert CM, Mittleman MA, Chae CU, Lee IM, Hennekens CH, Manson JE. Triggering of sudden death from cardiac causes by vigorous exertion. *The New England journal of medicine*. 2000;343(19):1355-61.
34. Whang W, Manson JE, Hu FB, Chae CU, Rexrode KM, Willett WC, et al. Physical exertion, exercise, and sudden cardiac death in women. *JAMA : the journal of the American Medical Association*. 2006;295(12):1399-403.
35. Corrado D, Migliore F, Basso C, Thiene G. Exercise and the risk of sudden cardiac death. *Herz*. 2006;31(6):553-8.
36. Thompson PD, Franklin BA, Balady GJ, Blair SN, Corrado D, Estes NA, 3rd, et al. Exercise and acute cardiovascular events placing the risks into perspective: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism and the Council on Clinical Cardiology. *Circulation*. 2007;115(17):2358-68.
37. Levine BD. Can intensive exercise harm the heart? The benefits of competitive endurance training for cardiovascular structure and function. *Circulation*. 2014;130(12):987-91.
38. La Gerche A, Heidbuchel H. Can intensive exercise harm the heart? You can get too much of a good thing. *Circulation*. 2014;130(12):992-1002.
39. Niederseer D, Moller J, Niebauer J. Increased rates of myocardial infarction and deaths in men after sexual activity. *International journal of cardiology*. 2012;156(2):234-5.
40. Yu S, Patterson CC, Yarnell JW. Is vigorous physical activity contraindicated in subjects with coronary heart disease? Evidence from the Caerphilly study. *Eur Heart J*. 2008;29(5):602-8.
41. Sayers SP, Clarkson PM. Exercise-induced rhabdomyolysis. *Current sports medicine reports*. 2002;1(2):59-60.
42. Randolph C. An update on exercise-induced bronchoconstriction with and without asthma. *Current allergy and asthma reports*. 2009;9(6):433-8.
43. Colbert JA. Clinical decisions. Cardiac screening before participation in sports—polling results. *The New England journal of medicine*. 2014;370(10):e16.
44. Sharma S, Estes NA, 3rd, Vetter VL, Corrado D. Clinical decisions. Cardiac screening before participation in sports. *The New England journal of medicine*. 2013;369(21):2049-53.
45. Hillsdon M, Foster C, Thorogood M. Interventions for promoting physical activity. *The Cochrane database of systematic reviews*. 2005(1):Cd003180.
46. Burtscher M, Bodner T, Burtscher J, Ruedl G, Kopp M, Broessner G. Life-style characteristics and cardiovascular risk factors in regular downhill skiers: an observational study. *BMC public health*. 2013;13(1):788.
47. Amesberger G, Finkenzeller T, Würth S, Müller E. Physical self-concept and physical fitness in elderly individuals. *Scandinavian journal of medicine & science in sports*. 2011;21:83-90.
48. Dela F, Niederseer D, Patsch W, Pirich C, Müller E, Niebauer J. Glucose homeostasis and cardiovascular disease biomarkers in older alpine skiers. *Scandinavian journal of medicine & science in sports*. 2011;21:56-61.
49. Finkenzeller T, Müller E, Amesberger G. Effect of a skiing intervention on the psycho-physiological reactivity and recovery in the elderly. *Scandinavian journal of medicine & science in sports*. 2011;21:76-82.
50. Finkenzeller T, Müller E, Würth S, Amesberger G. Does a skiing intervention influence the psycho-social characteristics of the elderly? *Scandinavian journal of medicine & science in sports*. 2011;21:69-75.
51. Flueck M, Eyeang-Békalé N, Héraud A, Girard A, Gimpl M, Seynnes OR, et al. Load-sensitive adhesion factor expression in the elderly with skiing: relation to fiber type and muscle strength. *Scandinavian journal of medicine & science in sports*. 2011;21:29-38.
52. Lauber B, Keller M, Gollhofer A, Müller E, Taube W. Spinal reflex plasticity in response to alpine skiing in the elderly. *Scandinavian journal of medicine & science in sports*. 2011;21:62-8.
53. Müller E, Gimpl M, Kirchner S, Kröll J, Jahnel R, Niebauer J, et al. Salzburg Skiing for the Elderly Study: influence of alpine skiing on aerobic capacity, strength, power, and balance. *Scandinavian journal of medicine & science in sports*. 2011;21:9-22.
54. Müller E, Gimpl M, Poetzelsberger B, Finkenzeller T, Scheiber P. Salzburg Skiing for the Elderly Study: study design and intervention – health benefit of alpine skiing for elderly. *Scandinavian journal of medicine & science in sports*. 2011;21:1-8.
55. Narici MV, Flueck M, Koesters A, Gimpl M, Reifberger A, Seynnes OR, et al. Skeletal muscle remodeling in response to alpine skiing training in older individuals. *Scandinavian journal of medicine & science in sports*. 2011;21:23-8.
56. Niederseer D, Ledl-Kurkowski E, Kvita K, Patsch W, Dela F, Mueller E, et al. Salzburg Skiing for the Elderly Study: changes in cardiovascular risk factors through skiing in the elderly. *Scandinavian journal of medicine & science in sports*. 2011;21:47-55.
57. Seynnes OR, Koesters A, Gimpl M, Reifberger A, Niederseer D, Niebauer J, et al. Effect of alpine skiing training on tendon mechanical properties in older men and women. *Scandinavian journal of medicine & science in sports*. 2011;21:39-46.
58. Aigner E; Niederseer D PW, Datz C, Müller E, Niebauer J. Alpine Skiing Improves Copper Imbalance in Untrained Middle-aged Subjects: a Randomized Controlled Trial. *Exp Clin Cardiol*. 2014;20(1):428-38.
59. Kahn JF, Jouanin JC, Bruckert E, Guezennec CY, Monod H. Physiological effects of downhill skiing at moderate altitude in untrained middle-aged men. *Wilderness & environmental medicine*. 1996;7(3):199-207.
60. Kahn JF, Jouanin JC, Espirito-Santo J, Monod H. Cardiovascular responses to leisure alpine skiing in habitually sedentary middle-aged men. *Journal of sports sciences*. 1993;11(1):31-6.
61. Ruedl G, Philippe M, Sommersacher R, Dunnwald T, Kopp M, Burtscher M. [Current Incidence of Accidents on Austrian Ski Slopes.]. *Sportverletzung Sportschaden : Organ der Gesellschaft für Orthopädisch-Traumatologische Sportmedizin*. 2014.
62. Burtscher M, Gatterer H, Flatz M, Sommersacher R, Woldrich T, Ruedl G, et al. Effects of modern ski equipment on the overall injury rate and the pattern of injury location in Alpine skiing. *Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine*. 2008;18(4):355-7.
63. Klug G, Schenk S, Dorler J, Mayr A, Haubner BJ, Alber H, et al. Occurrence of acute myocardial infarction in winter tourists: data from a retrospective questionnaire. *Clinical research in cardiology : official journal of the German Cardiac Society*. 2011;100(8):669-74.
64. Klug G, Schenk S, Dorler J, Alber H, Mayr A, Schachinger V, et al. Factors influencing the time-point of acute myocardial infarction in winter tourists. *International journal of cardiology*. 2011;149(1):136-7.
65. Chacornac M, Baronne-Rochette G, Schmidt MH, Savary D, Habold D, Bouvaist H, et al. Characteristics and management of acute ST-segment elevation myocardial infarctions occurring in ski resorts in the French Alps: Impact of an acute coronary care network. *Archives of cardiovascular diseases*. 2010;103(8-9):460-8.

66. Redelmeier DA, Greenwald JA. Competing risks of mortality with marathons: retrospective analysis. *BMJ*. 2007;335(7633):1275-7.
67. Burtscher M. Risk of cardiovascular events during mountain activities. *Adv Exp Med Biol*. 2007;618:1-11.
68. Burtscher M, Philadelphia M, Likar R. Sudden cardiac death during mountain hiking and downhill skiing. *N Engl J Med*. 1993;329(23):1738-9.
69. Faulhaber M, Flatz M, Burtscher M. Frequency of cardiovascular diseases among ski mountaineers in the Austrian Alps. *Int J Sports Med*. 2007;28(1):78-81.
70. Niederseer D, Ledl-Kurkowski E, Kvita K, Patsch W, Dela F, Mueller E, et al. Salzburg Skiing for the Elderly Study: changes in cardiovascular risk factors through skiing in the elderly. *Scandinavian journal of medicine & science in sports*. 2011;21 Suppl 1:47-55.
71. Faulhaber M, Flatz M, Gatterer H, Schobersberger W, Burtscher M. Prevalence of cardiovascular diseases among alpine skiers and hikers in the Austrian Alps. *High Alt Med Biol*. 2007;8(3):245-52.
72. Betik AC, Hepple RT. Determinants of VO₂ max decline with aging: an integrated perspective. *Appl Physiol Nutr Metab*. 2008;33(1):130-40.
73. Myers J, Prakash M, Froelicher V, Do D, Partington S, Atwood JE. Exercise capacity and mortality among men referred for exercise testing. *N Engl J Med*. 2002;346(11):793-801.
74. Ehsani AA, Spina RJ, Peterson LR, Rinder MR, Glover KL, Villareal DT, et al. Attenuation of cardiovascular adaptations to exercise in frail octogenarians. *J Appl Physiol*. 2003;95(5):1781-8.
75. Ades PA, Waldmann ML, Meyer WL, Brown KA, Poehlman ET, Pendlebury WW, et al. Skeletal muscle and cardiovascular adaptations to exercise conditioning in older coronary patients. *Circulation*. 1996;94(3):323-30.
76. Kuk JL, Saunders TJ, Davidson LE, Ross R. Age-related changes in total and regional fat distribution. *Ageing Res Rev*. 2009;8(4):339-48.
77. Mathieu P, Lemieux I, Despres JP. Obesity, inflammation, and cardiovascular risk. *Clin Pharmacol Ther*. 2010;87(4):407-16.
78. Slentz CA, Houmard JA, Kraus WE. Exercise, abdominal obesity, skeletal muscle, and metabolic risk: evidence for a dose response. *Obesity (Silver Spring)*. 2009;17 Suppl 3:S27-33.
79. Krautgasser S, Scheiber P, von Duvillard SP, Muller, E. Physiological responses of elderly recreational alpine skiers of different fitness and skiing abilities. *J Sports Sci Med* 2011; 10(4): 748-753.