

Research article

Physiological responses of elderly recreational Alpine skiers of different fitness and skiing abilities

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Abstract

We measured physiological responses of elderly recreational skiers of different fitness and skiing abilities. Six subjects (mean age: 61.2 ± 4.6 yrs; Wt: 76.8 ± 15.6 kg; Ht: 1.69 ± 0.10 m; BMI: 26.9 ± 5.0) were tested in a laboratory and during 30 and 75 min of recreational downhill skiing. Oxygen uptake (VO_2), heart rate (HR), blood lactate (LA) concentration, and diastolic (DBP) and systolic (SBP) blood pressure were used to estimate energy demands while skiing. During maximal testing in a laboratory, subjects achieved a mean maximal $\text{VO}_{2\text{max}}$ of 28.2 ± 7.5 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and a mean HRpeak of 165 ± 4 bpm ($98 \pm 1\%$ of HRmax). Mean maximal workload measured on a cycle ergometer was 2.2 ± 0.7 $\text{W}\cdot\text{kg}^{-1}$ with a mean LApeak of 7.4 ± 1 $\text{mmol}\cdot\text{l}^{-1}$. During field testing, mean VO_2 during skiing was 12 ± 2 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ($45 \pm 16\%$ of $\text{VO}_{2\text{max}}$). Skiing $\text{VO}_{2\text{peak}}$ was 19 ± 5 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ($72 \pm 23\%$ of $\text{VO}_{2\text{max}}$) was lower than $\text{VO}_{2\text{max}}$ in the lab ($p = 0.04$). Mean HR during skiing was 126 ± 2 bpm ($77 \pm 1\%$ of HRmax from lab tests). Skiing HRpeak was 162 ± 2 bpm. This was not different from HRmax in the lab ($p = 0.68$). Mean LA after 30 and 75 min of skiing was not different (2.2 ± 0.8 $\text{mmol}\cdot\text{l}^{-1}$ and 2.0 ± 0.8 , respectively, $p = 0.71$). Both LA samples during skiing were lower than lab tests ($p < 0.0001$). There was no difference for DBP between field and laboratory tests; however, SBP increased after 30 min of skiing to 171 ± 20 ($p < 0.009$) and 165 ± 17 ($p < 0.003$) after 75 min. These remained below the mean peak SBP determined in lab tests (218 ± 31). Mean oxygen demand during 30 and 75 min of recreational skiing is only 45% of $\text{VO}_{2\text{max}}$ while mean HR is 77% of HRmax. This departure from linearity not often seen in typical aerobic activities suggests that alpine skiing requires a combination of aerobic and anaerobic activity. Blood LA remained low during skiing suggesting that elderly skiers may govern their intensity via signals closer to VO_2 and LA compared to HR or BP.

Key words: Elderly, physiological responses, blood lactate, blood pressure.

Introduction

Numerous media outlets publicize alpine skiing as a predominantly fun and adventurous sport (Bässler, 1996). Skiing has been recommended as an appropriate activity for physically fit and healthy populations. It has also been labeled a risky, injury prone activity, especially for the elderly and physically unfit individuals (Brüggmann, 1974; Hollmann and Hettinger, 2000; Phlippen et al., 1970; Prokop and Bachl, 1984). However, the alpine skiing public is not only limited to young, healthy, fit generations; it often includes less fit individuals and a growing

number of elderly recreational alpine skiers (Bässler, 1996; Hansen, 2002; Lamprecht und Stamm, 2001).

Much of the research in alpine skiing has focused on ski racing and the associated changes in physiological demands or energy expenditure for successful ski racing and/or was designed to assess performance, training status, capacities and abilities of individuals or groups of alpine ski racers (Andersen and Montgomery, 1988; Bacharach and von Duvillard, 1995; Cortili et al. 1984; Tesch et al. 1978; Tesch, 1995; Veicsteinas et al. 1984; von Duvillard et al. 2009). Based on general conclusions from studies with elderly populations (Burtscher et al., 2000; 2005; Burtscher, 2004; 2007; Brüggmann, 1974; Faulhaber et al. 2007, Hollmann and Hettinger, 2000; Kahn and Jouanin, 1996, Phlippen et al., 1970; Prokop and Bachl, 1984) changes in cardiovascular responses to physical exertion may warrant medical attention prior to engaging in such activities. Acute changes possible during alpine skiing include increased blood pressure (BP), greater oxygen uptake (VO_2) and higher percentage of peak heart rate (HRpeak) at submaximal levels.

Therefore, the purpose of this study was to measure physiological responses in a group of elderly individuals having different skiing abilities and different fitness levels, first in a laboratory setting and then during recreational alpine skiing in hopes of demonstrating recreational alpine skiing is not only an activity for a healthy, physically fit, younger population.

Methods

This study was approved by the local ethics committee and a written informed consent was obtained from all participants prior to all testing.

Subjects

Six (3 male and 3 female) subjects (mean age: 61.2 ± 4.6 yrs; weight: 76.8 ± 15.6 kg; height: 1.69 ± 0.10 m; BMI: 26.9 ± 5.0) completed a single maximal laboratory test on an electronically braked cycle ergometer and on a separate day a 75 min recreational alpine skiing field test.

Subjects varied in skiing ability ranging from low to high intermediate level and were classified according to the Austrian Ski Teaching Concept 2007 (Wörndle, 2007). Participants documented a wide range of skiing days per year but not less than seven days per year and started to ski on an average age of 9 yrs, thus, subjects were skiing a total of 49 ± 10 years.

Table 1. Physiological characteristics of subjects during cycle ergometry in laboratory tests.

Subject	HRmax (bpm)	VO ₂ max (ml·kg ⁻¹ ·min ⁻¹)	Peak LA (mmol·l ⁻¹)	Workload max (W·kg ⁻¹)
1	162	33.5	8	2.6
2	158	22.1	9	1.8
3	167	27.6	6.2	1.9
4	165	39.6	7.3	2.9
5	167	27.3	6.6	2.7
6	169	19.1	7.5	1.2
Mean (±SD)	165 (4)	28.2 (7.5)	7.4 (1)	2.2 (0.7)

Laboratory test

Subjects completed a single incremental cycle test on an electronically braked cycle ergometer to volitional fatigue (Ergoline, Ergoselect, Reiner, Austria). The cycle ergometer test started with a workload of 50 W followed by a 25 W increase every 3 min until exhaustion. Heart rate (HR) beats per minute (bpm) was measured and recorded continuously via 12-lead ECG (Cardio Soft, Marquette, Hellige, Germany). Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured via auscultatory method (MPÖ Konstante II, FB, Bosch Medizintechnik, Germany) at the end of each increment. Respiratory gas exchange measures were assessed via an open-air spirometry system (Masterscreen CPX, Jäger, Germany) for determination of selected respiratory gas exchange measures of maximal oxygen uptake (VO₂max), carbon dioxide production (VCO₂), and pulmonary ventilation (V_E). All subjects reached the criteria for VO₂max (plateau in VO₂ at volitional exhaustion and an increase in VCO₂ associated with hypercapnic activity). Additionally, blood lactate concentration (LA) was measured at rest, at the end of every increment and at the end of the maximal effort via fully enzymatic amperometric analysis instrument (EBIO Plus, Eppendorf, Germany).

Throughout this manuscript, maximal laboratory values are compared to peak field test data and reported at percentages of max and peak data to associate physiological demand of our elderly subjects during recreational alpine skiing to their maximal efforts performed in the lab.

Field test

Subjects participated in a total of ~ 75 min of alpine skiing on slopes of the Maiskogel in Kaprun, Salzburg, Austria at an altitude of 1128-1730 m. Subjects resided at various altitudes ranging from 300-800 m and did not appear to be limited in their ability to ski at these latitudes.

The ski slopes consisting of < 25 % to < 40 % grade were used for testing and were serviced by a chair lift that required approximately 12 min for a subject to arrive at the top of the testing area. The weather conditions were sunny and temperature throughout testing days was consistent ranging between -2°C in the mornings to +10°C in the afternoons.

Participants were requested to ski at their normal speed using their preferred technique, stopping to rest and thus skiing at their own self selected pace.

To familiarize the subjects with the portable metabolic measurement system (Cosmed, K4b², Rome, Italy), each subject was asked to ski one preliminary run with the

respiratory gas exchange measuring equipment while wearing the respiratory gas exchange mask. This familiarization run also served as a warm-up and to obtain knowledge of slopes, snow conditions, and environmental conditions that were present for subsequent testing.

Each subject's HR and respiratory gas exchange data were monitored continuously during 75 min of alpine skiing. Raw data for VO₂ were filtered using a moving average of 15 breaths to eliminate non physiological spikes. Both HR and VO₂ responses during skiing were quantified with average and peak values during downhill-runs. Due to various logistical reasons, the use of different metabolic measurement systems between laboratory tests (Masterscreen CPX, Jäger, Germany) and field tests (Cosmed, K4b², Rome, Italy) were used. Reported validity and reliability measures of 3-5% for each system are well within the expected variance of these data.

Measures for BP (Omron, RX Classic, Mannheim, Germany) and LA (EKF, Biosen 5040, Magdeburg, Germany) were measured twice after downhill-runs. Recordings for BP were conducted immediately after downhill-runs at 30 min of skiing and the again after 75 min of skiing. Blood LA was measured approximately 1 min after downhill-runs at 30 and 75 min of skiing, respectively.

Statistical analyses

Statistical significance was set at $p < 0.05$. All statistical calculations (means \pm standard deviations), t -tests for maximal values obtained in the laboratory and peak values measured during on snow skiing. An analysis of variance (ANOVA) was performed using data from the laboratory, 30 min and 75 min of testing. Each time interval chosen was used to compare energy demands of early to late recreational skiing. Statistical analysis was conducted with SigmaStat version 3.5 software (Systat, Richmond, California, USA).

Results

Laboratory test

Table 1 shows individual data and group means (\pm SD) for maximal HR (HRmax), maximal VO₂ (VO₂max), workload and maximal blood LA (LAm_{ax}) measured during the ergometry test. Resting mean SBP/DBP was 126/79 mmHg and at exhaustion, it increased to 217/86 mmHg.

Field test

Mean and peak absolute and relative HR data are shown in Table 2. Participants reached a mean HR during downhill skiing of 126 ± 15 bpm or $77 \pm 9\%$ (range 64-91%) of

Table 2. Mean and peak absolute and relative HR data (\pm SD) during downhill skiing

Subject	Mean HR absolute (bpm)	Mean HR relative (% of HRmax)	Peak HR absolute (bpm)	Peak HR relative (% of HRmax)
1	120 (4)	74 (2)	164 (7)	101 (5)
2	118 (6)	75 (4)	156 (9)	99 (6)
3	108 (3)	64 (2)	148 (12)	89 (7)
4	126 (4)	80 (3)	155 (6)	94 (4)
5	128 (4)	76 (3)	158 (9)	95 (6)
6	153 (1)	90 (1)	191 (8)	113 (5)
Mean (\pmSD)	126 (15)	77 (9)	162 (15)	99 (8)

HRmax. Peak HR was 162 ± 15 bpm that corresponded to $98 \pm 8\%$ (range 87-113%) of HRmax and a comparison between lab and field values were not different ($p = 0.68$).

The mean VO_2 peak for subjects during skiing was $19 \pm 5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ($72 \pm 23\%$ of VO_2 max) and this was significantly lower than VO_2 max measured in the lab ($p = 0.04$). Mean VO_2 during skiing was $12 \pm 2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ($45 \pm 16\%$ of VO_2 max) (Table 3) ranging between 30-66% of VO_2 max for the entire group.

Blood LA measured one min after 30 and 75 min of downhill skiing ranged between 1.0 - $3.0 \text{ mmol}\cdot\text{l}^{-1}$ (Table 4). No differences were noted between LA at 30 min ($2.2 \pm 0.8 \text{ mmol}\cdot\text{l}^{-1}$) and 75 min ($2.0 \pm 0.8 \text{ mmol}\cdot\text{l}^{-1}$) of skiing ($p = 0.74$); however, both of these values were significantly lower than peak LA values from the lab tests ($p < 0.0001$) (Figure 1).

Table 4 also shows BP values recorded twice while skiing. Average BP values measured immediately after downhill skiing for the group were similar at 30 and 75 min of skiing ($p > 0.05$). Compared to lab test data, SBP at 30 min of alpine skiing was lower than peak SBP in the lab test ($p = 0.009$) while DBP was not different ($p > 0.05$). Similar results were recorded at 75 min of alpine skiing where SBP was also lower than peak SBP in the lab tests ($p = 0.003$), while DBP was not different ($p > 0.05$).

Discussion

Laboratory tests

With a workload range between 1.2 - $2.9 \text{ W}\cdot\text{kg}^{-1}$ at exhaustion, a wide range of fitness level was evident in this group of elderly skiers. Similar results were also observed for VO_2 max values, which ranged between 19 - $40 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Thus, it is important to note the heterogeneity of this group of elderly alpine skiers.

Field tests

In general, alpine skiing may be classified as an intermittent activity (Scheiber et al., 2009, Zintl and Eisenhut 2001) that requires both aerobic and anaerobic demands.

This is supported by data for single downhill skiing runs. Time to complete one run ranged from 2.8 min for better skiers to ~ 20 min for less skilled skiers. This adds additional support to the notion that these subjects represent a wide range of skiing abilities and levels of fitness often seen in the alpine skiing public.

Mean HR during downhill runs ranged between 64-91% of HRmax. Kahn et al. (1993) reported values between 70-78% of HRmax. Similar data for mean HR during recreational alpine skiing in elderly were reported by Krautgasser et al. (2009) and Scheiber et al. (2009).

Peak HR during alpine skiing ranged between 87-113% of HRmax for the elderly subjects in this study. Peak HR values for young alpine ski racers have been reported during competition to have a similar range (Anderson and Montgomery, 1988; Tesch, 1995). For some subjects peak HR values during downhill skiing exceeded maximal values recorded at exhaustion in the laboratory test. These high peak HR values may be the result of an increase in static loading of the lower extremities as a result of isometric contraction during ski turns in comparison to the dynamic movement exhibited during the cycle ergometer test (Cortili et al. 1984; Hollmann and Hettinger, 2000).

Individual VO_2 values during downhill skiing ranged from 30-66% of VO_2 max and were similar to the VO_2 range reported by Scheiber et al. (2009) in a guided group of elderly recreational skiers. The VO_2 peak values in our group of elderly skiers ranged from 47-100% of VO_2 max. Different percentages of VO_2 max measured during the lab tests were observed during skiing. Subjects with the lowest VO_2 max value showed the highest mean VO_2 response during skiing. It is difficult to determine the relationship of low physical fitness with elevated skiing demands due to the influence of various internal and external factors on skiing performance (Krautgasser et al. 2009); however, it may be reasonable to assume that all subjects require a similar level of aerobic capacity to successfully perform the skiing task of this study. Those subjects with a low aerobic capacity required a greater percentage of that capacity to ski for 75 min, hence a

Table 3. Mean and peak relative VO_2 and % VO_2 max data (\pm SD) during downhill skiing.

Subject	VO_2 mean ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	VO_2 mean (% of VO_2 max)	VO_2 peak ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	VO_2 peak (% of VO_2 max)
1	10 (1)	30 (4)	16 (2)	47 (4)
2	12 (2)	55 (9)	20 (1)	88 (5)
3	9 (1)	31 (4)	16 (2)	56 (6)
4	13 (1)	34 (3)	20 (1)	51 (3)
5	15 (1)	56 (4)	28 (2)	100 (7)
6	13 (1)	67 (3)	17 (0)	88 (1)
Mean (\pmSD)	12.0 (2.2)	45.5 (15.8)	19.5 (4.5)	71.8 (23.1)

Table 4. Blood lactate (LA) and systolic blood pressure (SBP) values at 30 min and 75 min of skiing .

Subject	LA at 30 min (mmol ⁻¹)	LA at 75 min (mmol ⁻¹)	SBP at 30 min (mm Hg)	SBP at 75 min (mm Hg)
1	1.47	1.06	179	176
2	2.13	2.03	180	173
3	1.15	1.01	180	173
4	2.65	2.42	155	140
5	3.04	2.98	193	179
6	2.72	2.65	138	146
Mean (±SD)	2.2 (.8)	2.0 (.8)	167.3 (21.8)	161.3 (17.6)

higher mean VO_2 for subjects with a lower VO_{2max} .

Blood LA have been recorded under many different conditions for alpine skiing. Von Duvillard et al. (2009) reported mean blood LA concentrations measured at peak exercise in laboratory tests of 13.7 mmol⁻¹ and 3 min after GS on-snow training run of only 5.6 mmol⁻¹. Anderson and Montgomery (1988) reported blood LA values of 9.0-13.0 mmol⁻¹ in a group of young elite ski racers after slalom and giant slalom competition. Tesch et al. (1978) analyzed muscle fiber lactate accumulation and reported LA values of 12.0 mmol⁻¹ and higher after a giant slalom ski race. This suggests that alpine skiing and ski racing appears to be an intermittent activity of moderately high intensity and thus, energy production depends greatly on both aerobic and anaerobic energy sources that result in substantial blood LA production.

For the elderly subjects in this study, all blood LA values remained between 1.0-3.0 mmol⁻¹ at 30 and 75 min of recreational alpine skiing. Scheiber et al. (2009) who studied nine skilled and experienced older alpine skiers found LA value ranging from 0.7 and 6.0 mmol⁻¹ during guided skiing. Subjects in the study of Scheiber et al. (2009) were very well skilled and had to perform defined skiing patterns that could have easily resulted in higher LA values compared to LA values of skiers in this study. With a wide range of intermediate skiing abilities and a self determined pace and intensity, it would not be too unexpected to record LA values in the range seen here.

The current group of recreational skiers who skied for 75 min are not comparable to young alpine racers or to

older more advanced ability skiers such as the ones used by Scheiber et al (2009). These current data do however reflect an intermittent character of activity during downhill skiing in spite of having relatively low blood LA values. Whether this low LA is a result of technical abilities of our elderly recreational skiers or a product of the skiing protocol allowing subjects to self regulate their skiing pace, cannot be determined.

Blood pressure was recorded immediately after downhill skiing for 30 and 75 min. Mean SBP measured right after skiing remained below maximal levels for all subjects. These results are in agreement with Scheiber et al. (2009) who also reported submaximal BP levels in a guided group of elderly skiers after downhill runs.

Conclusion

It is quite evident that alpine skiing requires both aerobic and anaerobic capacities. It also appears that during 75 min of recreational skiing by older intermediate level skiers, the oxygen demand ranged from 40-50% of VO_{2max} while at the same time HRs range from 70-80% of peak HR. When compared to typical aerobic activity of elderly, such as walking or cycling, there seems to be a greater demand on HR versus VO_2 ; yet, given blood LA remained low during skiing, elderly skiers may govern their intensity via signals more closely in tune to VO_2 and blood LA rather than HR or BP. Limitations of this study included a small number of subjects and each subject was allowed to control his/her own skiing intensity and duration. The intermittent character of alpine skiing allowed

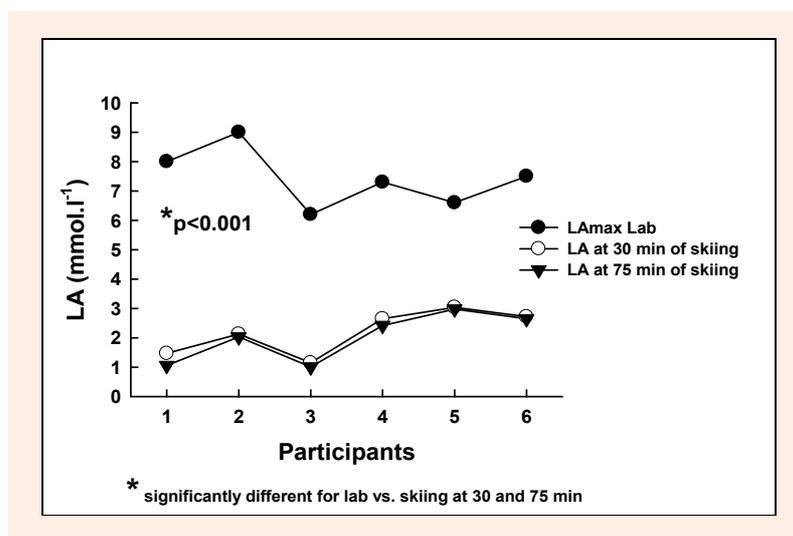


Figure 1. Peak blood lactate values between laboratory test and 30 and 75 min of skiing. Laboratory test values were significantly higher than blood lactate measured during skiing ($p < 0.001$).

individuals to tailor their skiing with regard to personal health and physical capacity. The chosen skiing slopes and their characteristics, the frequency and length of downhill runs, the elected speed and resulting technique all needed to be synchronized to individual skiing skill level. This, in concert with their physical capacity, was chosen to achieve an optimal skiing intensity while also providing an enjoyable experience for the subjects. This however could have limited the potential for finding differences in physiological demands of the skiers.

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Key points

- Recreational Alpine skiing for elderly population does not pose health risks
- Blood pressure and heart rate during recreational Alpine skiing is retain within normal limits
- Blood lactate levels remain relatively low and do not contribute to fatigue
- Oxygen uptake and blood lactate are better markers of intensity in elderly Alpine skier compared to heart rate and blood pressure.

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