High Intensity Training and Energy Production During 90-Second Box Jump in Junior Alpine Skiers

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Abstract

Gross, M, Hemund, K, and Vogt, M. High intensity training and energy production during 90-second box jump in junior alpine skiers. *J Strength Cond Res* 28(6): 1581–1587, 2014—Alpine ski races can last up to 2.5 minutes and have very high metabolic demands. One limiting factor for performance is insufficient aerobic energy supply. We studied the effects of an 8-day interval training block on aerobic capacity ($\dot{V}O_2max$) and performance and physiology during the 90-second box jump test (BJ90), a maximal performance test employed to simulate the metabolic demands of alpine ski racing, in elite junior skiers. After 10 high-intensity interval training sessions, performed as cycling, running, or an obstacle course, $\dot{V}O_2max$ increased in all subjects by 2.5 ± 1.9 ml·minute^{-1}·kg^{-1} ($4.3 \pm 3.2\%$), as did maximal blood lactate concentration in a graded cycling test (before: 11.7 ± 1.3 mmol·L^{-1}, after: 14.8 ± 1.8 mmol·L^{-1}, both parameters $p \leq 0.05$). Performance (total jumps) and aerobic energy contribution ($63.3 \pm 2.8\%$) during the BJ90 did not increase as hypothesized; however, subjects altered their pacing strategy, which may have counteracted such an effect. Additionally, the present data support the practicality of the performance test used for mimicking the demands of alpine skiing.

Key Words interval training, $\dot{V}O_2max$, aerobic energy, energy contribution, jump performance, fatigue, alpine skiing

Introduction

Alpine ski races can last between 45 and 150 seconds, and metabolic demand lies above the maximal oxygen consumption ($\dot{V}O_2max$) (22,23). This intensity can lead to exceeding 90% of $\dot{V}O_2max$ within 90 seconds (17). The ability to maintain muscle power output in such situations is interdependent on critical power (CP), anaerobic and aerobic capacities, and the time constant (τ) of aerobic energy production ($\dot{V}O_2$ kinetics) (5,6,11). Limits to these parameters determine the imminence and severity of muscular fatigue, which result in reductions in power output and detriments to ski performance.

The 90-second box jump test (BJ90) has been employed to assess performance capacity in alpine skiers because it is supposed to simulate the muscular, coordinational, and metabolic demands of ski racing (4) (see description in Methods). Although one study has reported changes in BJ90 performance with a controlled training intervention (3), no physiological measurements were obtained during the test, so the mechanisms for the improvement were not clear. Furthermore, although often applied in the practice, previous scientific publications, most from the precarving era, have only included performance scores (1,3,4,9) and data on the metabolic character of the test, such as oxygen uptake and its kinetics or contributions of aerobic and anaerobic energy systems, are lacking.

A previous study from our laboratory employed a short concentrated block of high-intensity interval training (HIT) to quickly improve aerobic capacity in elite junior alpine skiers (3). Alongside a 7.5% improvement in $\dot{V}O_2max$ of male subjects, there was a 9.1% increase in cycling power at the second ventilatory threshold (VT_2), which is similar to CP, and significantly improved BJ90 performance (3).

Thus, although it appears that such HIT blocks represent an effective strategy for quickly improving $\dot{V}O_2max$ and BJ90 performance in skiers, the question remains as to the effect of a HIT block on the energy production pattern during the BJ90, which could relate to the energy production pattern during ski performance. Thus, we designed an experiment to investigate how specifically training the aerobic capacity influences energy production, fatigue, and performance in the BJ90. We hypothesized that, after a HIT block, in parallel to increasing their $\dot{V}O_2max$, subjects would generate a larger portion of energy aerobically during the BJ90, which would allow for improved performance.

Methods

Experimental Approach to the Problem

This study employed a nonexperimental design. Subjects carried out the training prescribed to them by their coaches,

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Journal of Strength and Conditioning Research

Table 1. Training and testing schedule during the study.*

Day	Morning	Afternoon
0	Pretest	
1	4 × 4′/3′ cycling	2 × 10 × 30″/30″ running
2	4 × 4′/3′ obstacle course	
3	4 × 4′/3′ cycling	2 × 10 × 30″/30″ running
4	Rest	
5	4 × 4′/3′ cycling	2 × 10 × 30″/30″ running
6	4 × 4′/3′ obstacle course	
7	Rest	
8	4 × 4′/3′ cycling	2 × 10 × 30″/30″ running
9	Rest	
10	Coordination	
11	Agility, base endurance	
12	Agility and upper body strength	
13	Coordination	
14	Posttest	

*Ten high-intensity interval training sessions were performed between days 1 and 8. Days 9–13 comprised only light training, so as to promote recovery and adaptation before posttesting.

namely an 8-day HIT block designed to increase $\dot{V}O_2$max. There was no control group and no additional intervention by the investigators. One day before and 6 days after the training block in a controlled setting at the same time of day, $\dot{V}O_2$max test and the BJ90 were carried out, with assistance of the investigators, to see how training-induced changes to $\dot{V}O_2$max would affect BJ90 performance (see study timeline in Table 1).

Subjects

Nine male elite junior alpine skiers from an elite sport school (Nationales Leistungszentrum Engelberg, Switzerland) participated in the study. Their mean ± *SD* age, body weight, and body fat percentage were 16.8 ± 1.3 years (range 16–18), 70.6 ± 7.0 kg, and 11.2 ± 1.7%. Participants were experienced competitors and voluntarily underwent all testing procedures, which were conducted within the context of their normal performance evaluation, and which complied with the Helsinki's Declarations (Ethical Committee of Canton Lucerne, No. 13,076). Athletes and their parents were informed in detail about all test procedures and risks and gave their oral consent before data collection.

Procedures

Each subject visited the testing facility once before (pre) and once after the intervention (post), at the same time of day, for a series of measurements. Initially, skinfolds were taken from 7 anatomical sites for the determination of body fat percentage using the equation from Jackson and Pollock (12). Subjects then warmed up at a self-selected intensity on cycle ergometer for 15 minutes.

After the warm-up, subjects performed 3 maximal trials each, separated by 20 seconds, of the countermovement

Table 2. Physiological parameters (mean ± *SD*) during and after the 90-second box jump test (BJ90) for all 9 subjects and postexercise data ($EPOC_5$) provided by a 4-subject subset with selected correlations to performance (total jumps).*

	All subjects (*n* = 9)					Subset (*n* = 4)	
	Pre	Post	*p* time	*r*	*p* correlation	Pre	Post
TD (s)	3.4 ± 1.9	3.8 ± 2.3	0.75			3.0 ± 1.4	4.5± 1.0
τ (s)	11.4 ± 2.5	12.6 ± 2.7	0.26			13.3 ± 1.7	13.5 ± 1.7
MRT (s)	14.9 ± 2.1	16.3 ± 1.9	0.06	0.02	0.92		
$\dot{V}O_2$base (ml·min^{-1})	721 ± 121	807 ± 144	0.06			671 ± 165	775 ± 96
$\dot{V}O_2$peak (ml·min^{-1})	3,904 ± 499	4,095 ± 558	0.03	0.42	0.08	3,712 ± 464	3,946 ± 479
$\dot{V}O_2$ampl (ml·min^{-1})	3,182 ± 413	3,288 ± 421	0.10	0.44	0.07		
Net O_2 cons. (ml)	4,005 ± 559	4,062 ± 550	0.54	0.42	0.08	4,765 ± 568	4,985 ± 601
$EPOC_5$ (ml)						2,731 ± 187	2,888 ± 249
BLa (mM)	14.5 ± 0.8	14.7 ± 0.8	0.66	−0.28	0.27		

*TD = time delay; τ = time constant; MRT = mean response time of $\dot{V}O_2$ on-kinetics; $\dot{V}O_2$base = $\dot{V}O_2$ during 30 seconds preceding the test; $\dot{V}O_2$ampl = amplitude of $\dot{V}O_2$response; O_2 cons. = net oxygen consumption during test; $EPOC_5$ = net oxygen consumption in the initial 5 minutes after test; BLa = blood lactate 4 minutes after test.

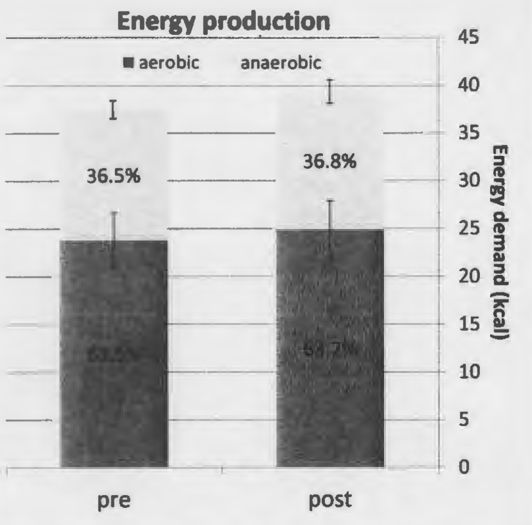

Figure 1. Total energy demand and proportions of aerobic and anaerobic energy supply to meet this demand during the 90-second box jump test before (left-hand bar) and after (right-hand bar) an 8-day high-intensity interval training block ($n = 4$).

(CMJ) and squat jump (SJ) on a Quattro Jump force plate with accompanying (version 1.07) software (Kistler Instruments, Winterthur, Switzerland). Analyzed parameters for both jumps were jump height (H), maximum concentric power production normalized to body weight (P_{max}), both averaged from the 3 trials, and the effect of prestretch (ration of height in CMJ to height in SJ, expressed as percentage).

Next, subjects performed a graded exercise test (GXT) to exhaustion on an Ergometrics 800S cycle ergometer (ergoline GmbH, Bitz, Germany) whereas spirometric data were gathered using the Oxycon Alpha spirometry system (Erich Jaeger GmbH, Höchberg, Germany). After 2 minutes of rest and 3 minutes at 25 W, resistance was increased in a ramp-like fashion by 5 W every 10 seconds, until the subject could no longer maintain a pedaling cadence of 60 revolutions per minute (3). Heartrate (HR) was measured telemetrically with a Polar RS400 HR monitor (Polar Electro Oy, Kempele, Finland), and blood lactate concentration (BLa) was taken at the finger at 2-minute intervals during the GXT and immediately and 2 minutes after the GXT using the Lactate Pro analyzer (Arkray Factory Inc., AxonLab AG, Baden, Switzerland). Concurrent with BLa measurements, subjects were asked to rate their perceived exertion according to the 6–20 Borg's scale.

Maximal oxygen uptake ($\dot{V}O_2max$) and respiratory exchange ratio before test end (RER_{max}) were defined as the highest 30-second compiled values; the former was expressed in absolute (ml·minute^{-1}) and relative (ml·minute^{-1}·kg^{-1}) terms. Maximal power output (PO_{max}, W) was the final work rate attained. Maximal HR (HR_{max}, per minute) was the highest 5-second compiled value. Pulmonary gas exchange data were compiled into 15-second averages for determination of ventilatory thresholds (VT_1, VT_2). The VT_1 was identified initially by the V-slope method and confirmed by a concurrent rise in $V_E \cdot \dot{V}O_2^{-1}$ but not $V_E \cdot \dot{V}CO_2^{-1}$ relative to power output (PO). The VT_2 was identified by a further steepening of $V_E \cdot \dot{V}O_2^{-1}$ concurrent with a rise in $V_E \cdot \dot{V}CO_2^{-1}$ relative to PO. As such, both VT could be expressed in terms of absolute and relative (% max) $\dot{V}O_2$ ($\dot{V}O_{2VT}$), PO (PO_{VT}), HR (HR_{VT}), and through linear interpolation, BLa (BLa_{VT}).

Ten minutes after completing the GXT, subjects performed the BJ90. This test involved completing as many jumps as possible onto a box (width: 50 cm, height: 44 cm) while alternating right-to-left on jumping down. Subjects performed the test while connected to the same spirometric analysis system as before. The

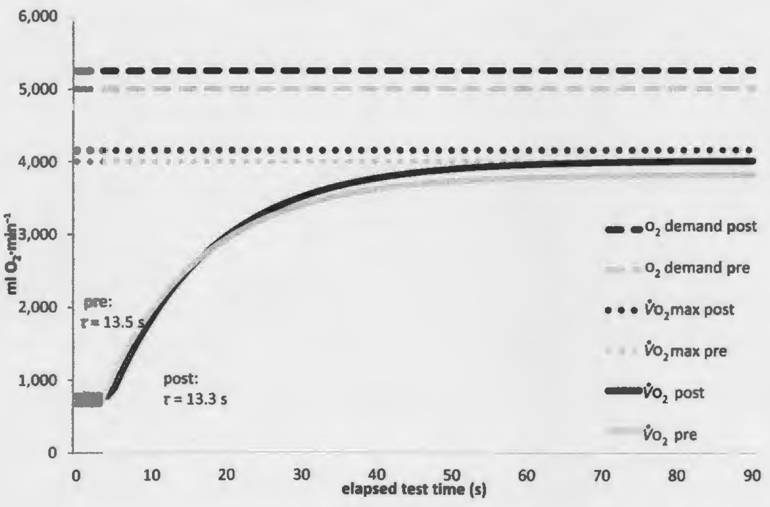

Figure 2. Mean $\dot{V}O_2$ response and mean calculated total O_2 demand ($n = 4$) during 90-second box jump test before (pre) and after (post) an 8-day high-intensity interval training block. Peak $\dot{V}O_2$ was increased after training (6.2 ± 3.9%, $p = 0.05$, $n = 4$) in proportion to the increased $\dot{V}O_2max$ (measured on a cycling ergometer). However, there was no significant change in total O_2 consumed (area under $\dot{V}O_2$) or $EPOC_5$ (net excess postexercise O_2 consumption over 5 minutes, see text for definition), intensity (i.e., theoretical O_2 demand, 126 ± 2% $\dot{V}O_2max$), aerobic energy contribution (63 ± 3%), or performance (total jumps).

BLa was taken at the finger 1 minute before and 2 and 4 minutes after the test. The BJ90 was familiar to all subjects.

Total jumps in the BJ90 were tallied after 30, 60, and 90 seconds. Fatigue indices were calculated as the percent change in jumps per 30-second segment. The $\dot{V}O_2$ was measured breath-by-breath beginning 1 minute before the test began. The data were filtered of measurements lying more than 3 *SD* apart from the previous breath. Data up until test end were then mathematically transformed to a best-fit exponential curve by minimizing residuals based on the following formula for the determination of $\dot{V}O_2$ on-kinetics:

$$\dot{V}O_2\ (t) = \dot{V}O_2\text{base} + A \times \left(1 - e^{-(t-TD)/\tau}\right),$$

where $\dot{V}O_2$ (t) is $\dot{V}O_2$ at time t; $\dot{V}O_2$base is baseline $\dot{V}O_2$ during the minute preceding the test; A is the amplitude of $\dot{V}O_2$ increase that is peak $\dot{V}O_2$ − $\dot{V}O_2$base; TD is the time delay; and τ is the time constant.

For 4 of the 9 subjects, $\dot{V}O_2$ off-kinetics were calculated in the same manner, whereby $\dot{V}O_2$ base was taken from the last 30 seconds of the test. Excess postexercise O_2 consumption was measured over the initial 5 minutes of recovery ($EPOC_5$). Based on pilot data, $EPOC_5$ provides the best estimate of the O_2 deficit and therefore the anaerobic energy production in supramaximal exercise of this intensity and duration (15). Thus, we also compared total O_2 consumption during the test to $EPOC_5$ to express proportions of aerobic and anaerobic energy. The other 5 subjects performed additional CMJ 3 minutes before and 1 minute after the BJ90 to determine the degree of muscular fatigue induced by the BJ90 (7).

Training Intervention

Beginning the day after pretesting, subjects completed an 8-day HIT block, consisting of 10 HIT sessions (3,19–21). Sessions consisted either of four 4-minute intervals or 2 sets of 10 × 30 seconds–on/30 seconds–off, based on the protocol of Helgerud et al. (10). Training modes was either cycling, an obstacle course including agility drills, or running. This was followed by 5 days of light recovery training before to post-testing (Table 1).

Statistical Analyses

Data from pre- and post-tests were compared using repeated-measures t-tests with Microsoft Excel software. The level of significance was set at $p = 0.05$. Pearson's correlations were performed with SPSS statistical software (Version 19; IBM, Armonk, NY, USA). Effect sizes (d) of individual parameters were calculated as the absolute value of changes to the group mean divided by the pretest, between-subject *SD*. Results are reported as mean ± *SD*.

Using the descriptive data of the metabolic character of the BJ90, rough comparisons were made to the previously published data characterizing the metabolic demands of race-like ski runs. In this way, the validity of the BJ90 as a ski-specific performance test could be considered.

Table 3. CMJ height before (pre) and after the HIT intervention (post) under 3 stages of fatigue within each test session: before GXT, between GXT and the BJ90, and directly after the BJ90.*

	CMJ height (cm)					
	Before ramp test		Between tests		After box jump	
Subject	Pre	Post	Pre	Post	Pre	Post
1	54.7	54.2	52.8	51.3	47.0	45.7
2	54.3	51.9	51.7	49.7	49.7	48.8
3	47.3	45.6	47.1	47.0	39.8	44.4
4	51.5	52.7	54.5	54.4	50.2	47.6
5	48.5	47.3	44.3	47.8	41.3	44.1
Mean	51.2	50.3	50.1	50.0	45.6	46.1
SD	3.4	3.7	4.3	3.0	4.8	2.0

*CMJ = countermovement jump; HIT = high-intensity interval training; GXT = graded exercise test; BJ90 = 90-second box jump test.

Results

No significant changes occurred in subjects' anthropometric characteristics.

Table 4. CMJ P_{max} before (pre) and after the HIT intervention (post) under 3 stages of fatigue within the test session: before GXT, between GXT and the BJ90, and directly after the BJ90.*

	CMJ P_{max} ($W \cdot kg^{-1}$)					
	Before ramp test		Between tests		After box jump	
Subject	Pre	Post	Pre	Post	Pre	Post
1	59.4	55.9	58.9	55.0	52.1	49.8
2	61.6	57.2	62.4	59.0	60.7	58.4
3	51.3	51.1	51.9	50.2	47.8	51.7
4	54.8	56.4	59.3	58.8	57.2	54.6
5	54.0	52.9	51.9	52.6	49.4	51.6
Mean	56.2	54.7	56.9	55.1	53.4	53.2
SD	4.2	2.6	4.7	3.8	5.4	3.4

*CMJ = countermovement jump; HIT = high-intensity interval training; GXT = graded exercise test; BJ90 = 90-second box jump test.

Table 5. Physiological measures characterizing the 90-second box jump test (BJ90), which is designed to simulate the demands of competitive alpine skiing, compared with those of actual competition-like ski runs (16–18,22,23).

	BJ90	Ski race (slalom, GS)
Energy turnover ($kcal \cdot kg^{-1} \cdot min^{-1}$)	0.38	0.36–0.66 (18,22,23)
Aerobic contribution (%)	63	34–45 (18,22)
$\dot{V}O_2$peak (%max)	94	93 (17)
Blood lactate ($mmol \cdot L^{-1}$)	15	12–15 (16,22)

A 90-Second Box Jump

There was no change in BJ90 in terms of total jumps (pre: 90 ± 7, post: 91 ± 4, $p = 0.56$, $d = 0.2$), and only 3 of 9 subjects improved performance. During posttesting, BLa was higher at the onset of BJ90 (pre: 11.4 ± 1.7 $mmol \cdot L^{-1}$, post: 12.6 ± 1.7 $mmol \cdot L^{-1}$, $p = 0.01$), but not different at either 2 minutes (pre: 14.8 ± 0.9 $mmol \cdot L^{-1}$, post: 15.5 ± 1.0 $mmol \cdot L^{-1}$, $p = 0.12$) or 4 minutes after the BJ90 (pre: 14.5 ± 0.8 $mmol \cdot L^{-1}$, post: 14.7 ± 0.8 $mmol \cdot L^{-1}$, $p = 0.66$). In posttesting, subjects performed significantly fewer jumps in the first 30 seconds (pre: 35 ± 2, post: 33 ± 2, −5.3 ± 5.2%, $p = 0.01$, $d = 1.0$), which tended to be correlated ($r = -0.59$, $p = 0.1$) with somewhat slower $\dot{V}O_2$ mean response times (pre: 14.9 ± 2.1, post: 16.3 ± 1.9 seconds, $p = 0.06$, $d = 0.7$). However, fatigue indices between the first and second 30-second segments (pre: −16.4 ± 7.5%, post: −8.9 ± 5.1%, $p = 0.03$), as well as $\dot{V}O_2$peak (pre: 3,904 ± 499 $ml \cdot minute^{-1}$, post: 4,095 ± 558 $ml \cdot minute^{-1}$, +4.9 ± 5.2%, $p = 0.03$) were improved after training. Otherwise, there were no changes in $\dot{V}O_2$ response variables (Table 2).

During the BJ90, energy provided from aerobic sources was unaltered by training and represented 63.3 ± 2.8% of total energy (pooled pre- and post-data from 4-subject subgroup, see Figure 1). Energy demand corresponded to 126 ± 2% of cycling $\dot{V}O_2$max (pooled pre- and post-data from 4-subject subgroup, see Figure 2). Peak $\dot{V}O_2$ attained during the BJ90, when expressed in relation to cycling $\dot{V}O_2$max, was similar before and after training and corresponded to 92.7 ± 3.5% and 94.8 ± 5.4% of $\dot{V}O_2$max, respectively ($n = 9$). Although there were no significant correlations between physiological measures and performance, there were certain strong tendencies ($p < 0.1$) for performance to be related to some O_2 consumption parameters ($n = 18$, Table 2).

Graded Exercise Test

In posttesting, subjects cycled 23 ± 22 seconds longer (+3.0%, $p = 0.01$) in the GXT, which produced higher PO_{max} values (pre: 406 ± 33 W, post: 418 ± 38 W, +2.8 ± 2.7%, $p = 0.01$, $d = 0.4$). The $\dot{V}O_2$max (pre: 58.8 ± 2.0 $ml \cdot minute^{-1} \cdot kg^{-1}$, post: 61.4 ± 2.3 $ml \cdot minute^{-1} \cdot kg^{-1}$, +4.3 ± 3.2%, $p = 0.004$, $d = 1.3$) and BLa (pre: 11.7 $ml \cdot minute^{-1} \cdot kg^{-1}$, post: 14.8 $mmol \cdot l^{-1}$, +27.9 ± 17.2%, $p = 0.001$, $d = 2.4$) were both significantly higher after training. Power output at VT_1 increased by 20 ± 23 W ($p = 0.03$), whereas PO at VT_2 was unchanged.

Countermovement Jump

There was a tendency ($p = 0.08$) for reduced P_{max} in CMJ (pre: 54.9 ± 5.6 $W \cdot kg^{-1}$, post: 53.5 ± 4.5 $W \cdot kg^{-1}$, $d = 0.2$), but no change in jump height (pre: 51 ± 3.6 cm, post: 50.6 ± 3.3 cm, $d = 0.1$) after the training intervention. No changes occurred in SJ height or P_{max}. The effect of prestretch on jump performance was also reduced from 9.2 ± 7.2% to 5.7 ± 5.0% ($p = 0.05$) after training.

Countermovement jump height (−4.2 ± 2.1 cm, −8.4 ± 4.2%, $p = 0.0002$, $d = 1.2$) and P_{max} (−2.7 ± 2.4 $W \cdot kg^{-1}$, −4.7 ± 4.3%, $p = 0.007$, $d = 0.6$, $n = 5$) were reduced acutely by the BJ90. However, when the fatigue-induced performance decrements were compared pre- and post-intervention, there was no significant effect of training either in terms of CMJ jump height (Table 3) or CMJ P_{max} (Table 4). Comparison of the metabolic character of the BJ90 and references from the previous publications on actual ski runs are displayed in Table 5.

Discussion

The main goal of this study was to assess training-induced effects of a short HIT block and their consequences on BJ90 performance and metabolism. After an 8-day HIT block, comprising 10 sessions, cycling $\dot{V}O_2$max and PO_{max} were significantly improved in junior development alpine skiers. However, in contrast to our hypothesis, we observed neither an increase in aerobic energy production nor an improvement in performance in the BJ90 after training. Similarly, the degree of muscular fatigue attributable to the BJ90, assessed by comparing single CMJ immediately before and after the test, did not appear to be affected by training.

The 4.3% improvement in $\dot{V}O_2$max was less than that observed by Breil et al. (3) after their 15-session, 11-day HIT block; however, considering to the number of HIT sessions performed, the effects appear to agree (0.43% per session in this study, compared with 0.5%). Nonetheless, unlike subjects in this study, the 9 male subjects in the study of Breil et al., (3) who increased $\dot{V}O_2$max by 7.5%, significantly improved BJ90 performance (pre 93 ± 6 jumps, post 97 ± 3 jumps, $p \leq 0.05$). Thus, it is possible that the present intervention was not strong enough to affect aerobic energy contribution, fatigue, or performance in the BJ90. However, another explanation for the unchanged aerobic energy contribution, despite improved aerobic capacity, could be the more conservative even-paced strategy that the athletes autonomously adopted in posttesting (2 fewer jumps in the first 30 seconds). Indeed, it has been shown that a fast-start or all-out pacing (adopted by the present subjects in pretesting) increases O_2 consumption in the first 2 minutes of high-intensity exercise and enhances exercise tolerance (2,13). Inversely, an even-paced approach, more similar to that adopted in posttesting in this study, increases the accumulated oxygen deficit (13) and reduces the aerobic contribution to total energy production (2). Thus, our subjects could well have inadvertently masked a training-induced improvement in their capacity for aerobic energy provision or indeed for a performance improvement (instead, both remained the same) by changing their pacing strategy. It is also possible that systemic exhaustion after the GXT was greater in posttesting (indicated by higher maximal BLa).

Regarding the unchanged effects of the BJ90 on CMJ parameters, we recognize that with only the subgroup of 5 subjects, statistical power was low; indeed, the probabilities of accepting a false null hypothesis were 92 and 75% for jump height and P_{max}, respectively (analysis performed post hoc with PASS 11 software; NCSS, LLC, Kaysville, UT, USA). Thus, relatively small effects, if real, could have easily been overlooked.

In addition to the main findings, metabolic measures which characterize the BJ90 were obtained in this study. These data confirm the test's practicality for simulating the physiological demands of ski racing. Indeed, especially comparable with the technical events, the test demands good bilateral coordination, explosive leg power, and large amounts of eccentric leg work, as well as near maximal aerobic and anaerobic energy production. Physiological data from this study compare well with data gathered elsewhere for the BJ90 (1) and during actual race-like skiing (Table 5). Although calculations for energy turnover and the aerobic proportion of energy production differ from the cited studies, differences are most likely because of shorter runs and different calculation methods used elsewhere (18,22,23). Indeed, our data suggesting that 63 ± 3% of energy comes from aerobic sources in the 90-second test correspond very well to the expected value for maximal exercise of this duration (8,14). Moreover, peak $\dot{V}O_2$ was similar to measurements during skiing.

Practical Applications

This study shows that a compact 8-day training block, comprising 10 high-intensity 4 × 4-minute interval sessions, improves $\dot{V}O_2max$ in elite junior alpine skiers with relatively similar effectiveness as other block concepts. Considering the many other time-demanding components of skiers' conditioning, this sort of compact and specific high-intensity training block is a time-efficient way to improve their aerobic capacity. Additionally, the study employed a mix of training modes during the interval sessions, which may reduce training monotony during the block. Moreover, this study provides important physiological data characterizing the BJ90, showing that this indoor performance test mimics the metabolic demands of ski racing quite well.

Acknowledgments

The authors thank the Swiss Olympic Committee for partially funding this project and the coaches at the Nationales Leistungszentrum in Engelberg for their cooperation.

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