Medicina Sportiva
Med Sport 16 (4): 159-164, 2012
DOI: 10.5604/17342260.1024776

ENERGY CONSUMPTION AND ENERGY BALANCE DURING THERAPEUTIC HIKING AND SKIING AS PART OF THERAPY FOR OBESE CHILDREN IN THE CLINIC SCHÖNSICHT BERCHTESGADEN*

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Abstract

Introduction: The mountain region of Berchtesgaden allows hiking and skiing more intensively as walking in the plain with desired consequences for the therapy of obese children and adolescents.

Objective: To assess the exact contribution of hiking and skiing as part of a global therapeutic concept.

Methods: Therefore 22 children of the clinic were tested on 2 hiking tracks and 11 children in winter on a cross-country skiing circle, using the transportable MetaMax-System measuring oxygen consumption and by this, the energy consumption.

Results: The additional energy consumption by these therapeutic activities amounted to: 13.7 kJ/kg for the short track (52 min), 39.6 kJ/kg for the long track (2:19 h) and 9.5 kJ/kg for 3 circles (29 min).

Conclusion: In relation to the strict hypocaloric diet these increases can be seen as relevant for the total metabolism, but a consequent diet remains still very important.

Key words: *Energy consumption hiking, energy consumption skiing, mountain medicine, movement therapy, obesity, sports therapy*

Introduction

Therapeutic mountain hiking and skiing is a main integral part of the therapy for obese children in the clinic Schönsicht (mountain region of Berchtesgaden). It is intended to increase the energy consumption of the children more by hiking up- and downhill as by walking in the plain. This should lead, together with other physical activities, diet and behavioral training to a distinct loss of weight. For the leader of the clinic it was unclear, which quantitative effect could be ascribed to this special physical treatment-program.

Several values of energy consumption during mountain hiking exist in literature, but they can only be used as orientation, because they were not valid for obese children and adolescents. As described e.g. [1,2], the metabolic rate of walking increases linearly with the additional loads that are carried. There is no influence by varied usual walking velocities, if consumption per meter is regarded.

An energy balance has to consider the caloric intake, too, especially drinks. Table 1 describes some examples.

The aim of the following therapy control studies was, to measure the energy consumption during the therapeutic hiking and skiing programs of the clinic by a mobile system, to get representative values for the children of the clinic. By this an energy balance, referring to the therapeutic programs, should be achieved.

Table 1. *Energy content of some drinks [3]*

Juice	ca. 470 kcal/L
Milk (3.7 % fat)	ca. 640 kcal/L
Beer	ca. 470 kcal/L

Methods

The measurements happened on two different mountain hiking tracks, a long track (11.3 km, max height-difference 768 m, ca. 2 ½ hours) and a short track (3.0 km, max. height difference 274 m, ca. 1 hours). The measurements were performed by Groß-Bölting [4] in august 2010 and by Gebhardt [5] in august 2011. Data of the children/adolescents are described in table 2; body weight was determined with clothes and measuring system. For calculation with a reference weight for resting values, estimated 3 kg (1.5 clothes, 1.5 measuring system) was subtracted from the values in table 2.

In winter time a part of the movement therapy consisted of cross-country skiing over a repeated circle of 587 m, max. height-difference: 4 m, ca. 10 min/circle.

*The results were presented during the "5th European Hypoxia Symposium Hypoxia, High Altitude Physiology and Sports in Science and Practice" which was held at Kühroint Training Centre of the German Federal Police near Berchtesgaden, Germany, September, 2011.

Table 2. *Means with SD and medians of the 22 hiking subjects. Long distance: n =10; 6 male, 4 female, short distance: n =12; 5 male, 7 female.*

	Height [cm]	Weight [kg]	BMI	Age [years]	Referenceweight forresting values	Referenceweight forexercise values
means	172 ± 10	106 ± 25	35 ± 6	16 ± 2	103 ± 24	106 ± 25
medians	173	105	34	17		

Table 3. *Means with SD and medians of the 11 skiing subjects (6 male, 5 female, not very experienced in skiing). Body weight without skiing clothes and equipment.*

	Height [cm]	Weight [kg]	BMI	Age [years]	Referenceweight forresting values	Referenceweight forexercise values
means	169 ± 4	99 ± 12	35 ± 4	15 ± 2	99 ± 12	103 ± 13
medians	169	97	35	14		

Table 4. *Diet procedure for the children/adolescents of the clinic [7]*

female	male
< 156 cm:1250 kcal/d	< 146 cm1250 kcal/d
156 – 180 cm:1500 kcal/d	146 – 170 cm:1500 kcal/d
>180 cm:1800 kcal/d	>170 cm:1800 kcal/d

Measurements were performed by Heß [6] in February 2010 over 3 circles. Data of the children/adolescents are described in table 3; the body weight was determined in underwear. The actual body weight including winter clothes and total equipment was estimated by adding 2.5 + 1.5 = 4 kg to the values of table 3.

Fig. 1. *Subject with the mobile system for measuring oxygen consumption*

The diet procedure is described in table 4. For clinical applications these and other energy values often are given in kcal and not in kJ.

For all measurements the mobile spirometry system MetaMax 3B® by Cortex® Leipzig (Fig. 1) was deployed. It is operating with breath by breath method [8] and has a weight of 1.5 kg (including the battery). Gas and volume sensors were calibrated daily before the measurements. Cold temperatures in winter time caused several methodical problems by condensing water, but nonetheless it was possible to achieve a measuring period of about 30 minutes. Energy consumption was calculated by the system, according to actual respiratory exchange ratio ("RQ").

All in a retest principle arranged experiments (for reliability) were done in a timeframe of one to five days between each first and second test.

Before starting, the subjects performed a 5 min-period of resting, that is not comparable with standard resting conditions. These values before the exercise were taken as basis of calculation for the additional energy consumption.

Results

Tables and figures for the long and the short hike track are extracted from the studies of Groß-Bölting [4] ($n_{long} = 4$ $n_{short} = 5$) and Gebhardt [5] ($n_{long} = 6$ $n_{short} = 7$). These values are summarized to a new number of cases: ($n_{long} = 10$ $n_{short} = 12$).

Values for cross country skiing with a number of cases of n=11 are taken from the study of Heß [6].

Resting values

Table 5 shows means ± s_D of the resting values, measured during a 5 minutes lasting period before and 5 (3, resp.) minutes after each hiking test. They were realized while the children were seated and reassured. The resting values are higher than the values before.

Mountain hiking

Total energy consumption: According to the total energy consumption of the studies of Groß-Bölting [4] and Gebhardt [5], given in table 6, the results demonstrate an increase by about four times of the resting values before. There is a noticeable difference between both studies regarded to the energy consumption per minute and kg. This difference turns considerably lower, if the consumption is related only to body weight, demonstrating the consumption over total distance (for short and long track, resp.).

Additional energy consumption: The additional energy consumption as difference between exercise values minus resting values (before) of both subgroups and the total group are described in table 7. The time demand for the same distance of the group Groß-Bölting (GB) was a little bit higher than the Gebhardt-values (G). Related only to body weight, for both subgroups, we found for both subgroups a good conformity of the additional energy consumption over the total distance.

Cross-country skiing

Total and additional energy consumption: According to the study of Heß [6], the children needed

Table 5. *Energy consumption during resting periods before(5 min) and after the exercise of the three studies from Groß-Bölting – GB [4], Gebhardt – G [5] and Heß – H [6] with number of cases (n)*

	N	Energy consumption (±SD) [J·min^{-1}·kg^{-1}]	
		Before	After
GB	9	71 ± 12	not available
G	13	106 ± 17	162 ± 36 (5 min)
H	11	93 ± 12	167 ± 29 (3 min)
total	33	94 ± 21	

Table 6. *Total energy consumption for the short (3.0 km, height diff. 274 m) and for the long hike track (11.3 km, height diff. 768 m), related to body weight and needed time or only as consumption per body weight (kg) over the total distance. GB = Groß-Bölting [4], G = Gebhardt [5]*

studies	number of cases = *n*		Total energy consumption [kJ·min^{-1}·kg^{-1}] ± SD		[kJ·kg^{-1}] ± SD	
	short track	long track	short track	long track	short track	long track
GB	5	4	0.31 ± 0.04	0.32 ± 0.04	17.6 ± 0.8	50.0 ± 4.6
G	7	6	0.39 ± 0.04	0.45 ± 0.08	18.6 ± 1.1	54.3 ± 4.8
Subtotal	12	10	0.36 ± 0.06	0.40 ± 0.09	18.2 ± 1.1	52.9 ± 4.9
Total	22	0.38 ± 0.08				

Table 7. *Additional energy consumption of both hiking studies (GB = Groß-Bölting [4], G = Gebhardt [5]) related to body weight and needed time and as consumption per body weight over the total distance*

study	time demand min ± SD		Additional energy consumption [kJ·min^{-1}·kg^{-1}] ± SD		[kJ·kg^{-1}] ± SD	
	short track	long track	short track	long track	short track	long track
GB	57 ± 7	162 ± 19	0.24 ± 0.04	0.24 ± 0.04	13.6 ± 1.1	38.7 ± 3.8
G	48 ± 6	123 ± 14	0.29 ± 0.04	0.33 ± 0.07	13.7 ± 1.2	40.2 ± 4.7
Subtotal	52 ± 7; *n* = 12	139 ± 25; *n* = 10	0.27 ± 0.04; *n* = 12	0.30 ± 0.07; *n* = 10	13.7 ± 1.1; *n* = 12	39.6 ± 4.3; *n* = 10
Total			0.28 ± 0.06; *n* = 22			

Table 8. *Energy consumption in cross-country skiing; study of Hess [6]*

Heß n=11	energy consumption			
	[kJ·min^{-1}·kg^{-1}] ± SD		[kJ·kg^{-1}] ± SD	
	total	additional	total	additional
	0.43±0,07	0.34+±0.07	12.3±1.6	9.5±1.4

Table 9. *Additional energy consumption and test-duration of the three studies*

	n = 33	Duration	Mean velocity [km/h]	Additional energy consumption [kJ·min^{-1}·kg^{-1}] ± SD	Additional energy consumption per distance [kJ·kg^{-1}]
Hiking, shortdistance	12	52 min	3.5	0.27±0.04	14.04
Hiking, longdistance	10	2: 19 h	4.9	0.30±0.07	41.70
skiing	11	29 min	3.6	0.34±0.07	9.86

a little bit more energy for skiing than in the hiking studies (table 8). The subjects needed for the first run 29:40 ± 5:07 and for the repeated run 28:29 ± 4:35 min.

Additional energy consumption of all studies: By comparing additional energy consumption of the three studies in Table 9, the values of the skiing study are a little bit higher just as the test-duration was shorter. Among the hiking studies, the children of the long track consumed more energy per minute.

Reliability

All studies show a high correlation for values of test and retest. Exemplarily the reliability of the study of Heß [6] is illustrated in Fig. 2.

Disscusion

The three studies were performed under field conditions. This includes some methodical problems, but these could be compensated by the higher

Table 10. *Reliability coefficients of the additional energy consumption per kg body-weight of all studies; based on test and retest*

Groß-Bölting [4]		Gebhardt [5]		Heß [6]
short track	long track	short track	long track	
n = 5	*n* = 4	*n* = 7	*n* = 6	*n* = 11
0,91	0,89	0,94	0,97	0,92

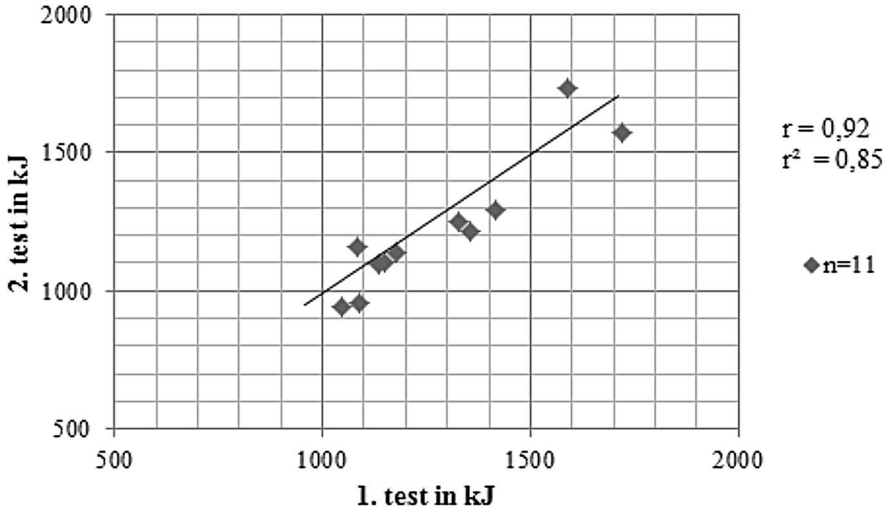

Fig. 2. *Correlation diagram of the values of the additional energy consumption in kJ over the whole distance of the study of Heß [6]; with number of cases (n) and identity line*

Table 11. *Energy balance for a 100 kg person*

	Hiking Short distance ca. 1 hr	Hiking Long distance ca. 2 ½ hr	Skiing (6 circles) ca. 1 hr
Daily demand (table 5) (for 100 kg)	94 J·min^{-1}·kg^{-1} = 13536 kJ/d ~ 3235 kcal/d	94 J·min^{-1}·kg^{-1} = 13536 kJ/d ~ 3235 kcal/d	94 J·min^{-1}·kg^{-1} = 13536 kJ/d ~ 3235 kcal/d
Minus diet (table 4)	1800 kcal/d	1800 kcal/d	1800 kcal/d
Energetic deficitby diet	1435 kcal/d	1435 kcal/d	1435 kcal/d
Additional energy consumption (table 9)	1404 kJ ~ 336 kcal	4170 kJ ~ 997 kcal	1972 kJ ~ 471 kcal
Demand plus additionalenergy consumption	3235 + 336 kcal = 3571 kcal	3235+ 997 kcal = 4232 kcal	3235 + 471 kcal = 3706 kcal
New deficit by dietand sports	3571 – 1800 = 1771 kcal/d	4232 – 1800 = 2432 kcal/d	3706 – 1800 = 1906 kcal/d
Increase of energetic deficit by sports	1771 – 1435 = 336 ~ 23 % of 1435 kcal/d	2432 – 1435 = 997~ 69 % of 1435 kcal/d	1906 –1435 = 471 ~ 33 % of 1435 kcal/d
Increase of energetic deficit by diet	1435 kcal/d ~ 81 % of 1771	1435 kcal/d ~ 59 % of 2432	1435 kcal/d ~ 75 % of 1906
Increase of energetic deficit by sports	336 kcal/d ~ 19 % of 1771	997 kcal/d ~ 41 % of 2432	471 kcal/d ~ 25 % of 1906

validity of our field related results in the context of our question.

We were surprised about the very good retest-reliability in the repeated experiments and the consistent results of comparable values, due to the reliability of the MetaMax-system and the carefulness of the 3 experimenters, especially in the measurements during winter.

The "resting values" taken before the start were used as values which are representative for the everyday metabolism without special physical activities. We needed such a value for calculations of the individual *additional* energy consumption by performing the special sports therapy. Tabular values from literature were seen as not adequate. Our values represent individual aspects such as age and body weight and they are undoubtedly higher than values derived from true resting conditions.

The gender of the subjects has not been considered (smaller case number), because there is no reason to suppose different levels of efficiency for females and males, however. The total number of cases was estimated as sufficient. The level of exertion and the amount of additional weight (with equipment) can be neglected, if the energy consumption is calculated in relation only to the total distance and body weight – with and without clothes and additional loads. For walking, the energy consumption per meter is nearly independent from velocity, but related linearly to additional weight. We assume the same for skiing.

Another problem was not regarded, so far. The respiratory exchange ratio ("RQ") during work includes also a respiratory aspect (exercise related hyperventilation) in addition to the metabolic condition. The MetaMax-System calculates the metabolism based on oxygen uptake, depending on the actual RQ-related energetic equivalent of oxygen. This problem is included and neglected in most similar cases; so we did also, because it is a small failure and has only principle relevance.

So our values are seen as adequate to assess the therapeutic effect of the performed physical activities for obese children and adolescents in comparison to the reduced diet. The energy balance for a person with 100 kg body weight can be calculated as follows (Table 11).

In this context, the comparison of diet and special physical activities, demonstrates how important additional physical activities and especially the calorie-reduced diet for the desired negative energy balance is.

Without doubt, endurance sports can improve the desired negative energy balance, but a strongly reduced caloric intake by food and drinks can not be achieved. The reduction of body weight as a complex process depends not only on a surely sufficient negative balance. But such a negative balance should be the basic principle for measures to reduce body weight.

As recommendation for clinical practice we propose: The therapeutic physical activities can improve the negative caloric balance relevantly, but these activities require at least 1 hr with adequate intensity (cf. in our case the velocities in Table 9). Discipline in diet is very important and should be trained and strongly supervised, especially the drinking behavior (Table 1).

Endurance sports generates hunger and thirst and by this an adequate behavioral training in the period after such sports is very important, too.

Acknowledgment

Thanks to the young subjects for their sportif cooperation in the clinic Schönsicht (Berchtesgaden) and Mittendorff-Institut (Berchtesgaden) for support.

Declaration of interest

The authors report no conflicts of interest.

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Accepted: September 03, 2012
Published: December 21, 2012

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