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10.20960/nh.02582

OR 2582

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# Efectos del alpinismo de altitud en la composición corporal: revisión sistemática

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**Received:** 14/03/2019
**Accepted:** 27/05/2019
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## ABSTRACT

High altitude mountaineering is characterized by high energetic requirements due to the environment in which the activity is developed: negative energy balance, extreme cold, high altitude and the assumption of potential risks can be found during the practice of this sport. High altitude mountaineering, as a result of the previous factors, induces changes in body composition which have never been studied previously in a systematic review. A search within four different databases (PubMed, SportDiscus, Scopus and Medline) was performed using the thesaurus terms "Mountaineering" and "Body composition". A second search was performed using the following terms "Altitude" and "Body composition". The selection criteria included studies with healthy adults which evaluated the effects of at least 14 days of uninterrupted stays at altitudes above 4,000 m. The studies included in the review assessed body composition through different methods such as anthropometry, bioimpedance, dual energy x-ray absorptiometry, hydrostatic weighing and air displacement plethysmography. The search was performed up to and including December 1st 2018. Eleven observational studies met the inclusion criteria. All studies reported weight loss, of which five reported significant reductions in lean mass and six reported reductions in fat mass. Also, three studies reported reductions in both fat mass and lean mass. Current evidence is limited to observational studies with important confounding factors affecting the final conclusions. Longitudinal studies with a better methodological design and control groups are needed in order to verify these results.

**Key words:** Mountaineering. Body composition. Altitude.



**RESUMEN**

El alpinismo a grandes altitudes se caracteriza por elevados requerimientos energéticos debido al ambiente en el que se desarrolla la actividad: los balances energéticos negativos, el frío extremo, la exposición a la altitud o niveles de estrés elevados se pueden observar en la práctica de este deporte. Debido a estos factores, el alpinismo de altitud induce cambios en la composición corporal que no se han estudiado previamente en una revisión sistemática. Se realizó una búsqueda en cuatro bases de datos (PubMed, SportDiscus, Scopus and Medline) con los términos Mesh *"Mountaineering"* y *"Body composition".* Una segunda búsqueda se realizó usando los términos *"Altitude"* y *"Body composition".* Los criterios de selección incluyeron estudios con adultos sanos que evaluaron los efectos de estancias de al menos 14 días ininterrumpidos en altitudes superiores a los 4.000 m. La composición corporal se analizó con diferentes métodos como antropometría, bioimpedancia, absorciometría dual de rayos x, pesada hidrostática y pletismografía por desplazamiento de aire. La búsqueda se realizó incluyendo estudios fechados hasta el 1 de diciembre de 2018. Once estudios observacionales cumplieron con los criterios de inclusión. Todos los estudios reportaron pérdida de peso, de los cuales cinco reportaron reducciones en masa magra; seis, reducciones en masa grasa; y tres, reducciones en ambas. La evidencia actual se limita a estudios observacionales con factores de confusión importantes que afectan a los resultados finales. Se necesitan estudios longitudinales con mejor diseño metodológico y grupo control para verificar estos resultados.

**Palabras clave:** Alpinismo. Composición corporal. Altitud.

## INTRODUCTION

High altitude mountaineering is a sport discipline with several important particularities. First, from a demographic point of view, a very scarce part of the world population lives at altitudes of 4,000 m above sea level (1). Long term stays at high altitudes and sudden altitude gains have been associated to several health problems such as high altitude pulmonary edema (2), high altitude cerebral edema (3), and acute mountain sickness (4). Moreover, transient neurological dysfunctions (5) and frostbite (6) have been frequently reported. During high altitude mountaineering, energy expenditure can rise and coexist with decreases in energy intake (7). Taking into account the environment in which the sport takes place, the particular demands of this discipline and the potential risks assumed by the practitioners, high altitude mountaineering can produce a big impact on the human body.

One of the main effects of prolonged high altitude stays is the change in body composition (8). To date, only few studies have evaluated the effects of prolonged high altitude mountaineering stays on basic aspects of body composition: weight, fat mass, fat free mass, and body fat percentage. Most of the tools normally used to assess body composition require a laboratory environment and specific protocols (9) that are difficult to implement in the typical environment of a high altitude expedition.

Thus far, there have not been any systematic reviews attempting to disclose the effects of high altitude stays on body composition. This systematic review aims to collect all currently available data on the subject and analyze the general effects of altitude on human body composition.

## METHODS

### Search strategy

The project followed the systematic review methodology proposed in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (10). The study was registered in the International Prospective Register of Systematic Reviews (PROSPERO) of the University of York under the registration number CRD42019119748. The identification of studies was performed by searching within PubMed, SportDiscus, Scopus and Medline. The search was conducted up to and including December 1$^{st}$ 2018. Two different searches were performed in each database to ensure that all published studies regarding the topic were included in the present systematic review. The first search was performed using the thesaurus provided by each database: mountaineering AND body composition, while the second search was performed with the following combination of terms: altitude AND body composition. Three reviewers independently examined each database to obtain the potential publications. Full texts of the relevant articles were obtained and assessed against the inclusion and exclusion criteria described below. Inter-reviewer disagreements were resolved by consensus.

### Inclusion criteria

The following inclusion criteria were used: a) types of studies: cross-sectional, longitudinal, randomized, and nonrandomized controlled trials studying the effects of high altitude mountaineering on body composition, with or without other interventions; b) types of participants: healthy adults; and c) types of outcome measured: body mass, fat mass, fat free mass and percentage of body fat measured through anthropometry, dual-energy x-ray absorptiometry, body plethysmography, hydrostatic weighing and bioimpedance analysis.

**Exclusion criteria**

The following exclusion criteria were used: a) studies in languages other than English or Spanish; b) unpublished data; c) studies with animals; d) studies that measured body composition but without specifying the method used; e) studies with reported altitudes below 4,000 meters above sea level; f) studies which reported stays above 4,000 meters that were shorter than 14 uninterrupted days; g) studies performed in hypobaric chambers or other altitude simulating environments; h) studies that did not include mountaineering activities during the altitude stay; and i) dissertations or abstracts from society proceedings or congresses and other similar unpublished data.



**Quality assessment**

As all of the studies included in the review were observational, original research was assessed using the United States National Institutes of Health (NIH) tool for observational studies. The NIH scale consists of 14 items related to scientific rigor (11). The results of the quality assessment can be seen in table I. Eleven studies met the inclusion criteria. To date, there has not been a previous systematic review about this subject so a comparison of the review system used could not be performed. Consensus was achieved on scores given to the eleven articles. A fourth reviewer to solve scoring issues was not needed in this case. The Kappa value (measure of observed agreement) for all eleven articles was 1.0 (perfect agreement).

### Data extraction

All the articles were assessed first according to the title; second, according to the abstract; and lastly, a full review of the article was performed. Figure 1 represents the PRISMA flow chart of the process of study selection. Article selection was performed using a continuous string quadrant in Microsoft Excel 2007. The main variables can be consulted in table II.

## RESULTS

### Selection and inclusion of studies

A total of 23 full text papers that possibly met the inclusion criteria were examined exhaustively for further consideration (Fig. 1). Some of the included studies were conducted at altitudes below 4,000 m, others presented a follow-up period shorter than 14 days, and in some cases there was insufficient data about the method used for the evaluation of body composition. Furthermore, one study that met all the inclusion criteria was conducted in a hypobaric chamber. One last study also met the inclusion criteria but did not involve mountaineering activities during the altitude stay. All these studies were excluded from further analysis. Therefore, eleven studies that included a total of 91 participants were included in the systematic review. The reported altitudes, as it can be seen in table II, varied between 4,300 and 8,848 meters. Stays reported in the studies lasted between 16 and 53 days.

### Methods of assessing body composition

Of the eleven studies that were included in the qualitative analysis, seven used anthropometry alone to assess body composition (8,12-17). Two combined anthropometry with bioelectrical impedance

(18,19), one (20) used DEXA and another one used air displacement plethysmography (21).

**Effects of high altitude mountaineering on body composition**

The effects of altitude stays on body composition reported by each study can be seen in table III. All of the studies included in this review reported significant reductions in total mass (2.6 to 4.9 kg). Six studies reported significant fat mass loss (0.9 to 5.1 kg) and another five reported lean mass loss (0.8 to 3.5 kg). Furthermore, three studies found decreases both in fat mass and lean mass. Two studies reported weight loss without significant decreases in fat mass and lean mass.

## DISCUSSION

This was the first systematic review about the effects of high altitude mountaineering on body composition. The main findings were: a) high altitude stays induced weight loss in all studies included in the review; and b) weight loss was caused by reductions in fat mass and lean mass distributed unequally between studies. These findings are limited by the characteristics of the studies included in the review, which included small sample sizes, variations of the altitudes reached by subjects included in the same study, and different methods for assessing body composition.

The findings obtained in this review support the fact that stays at high altitudes induce significant reductions in total mass. Rose et al. (22) and Westerterp et al. (7) discussed that the weight loss observed during high altitude expeditions could be explained by the energy balance changes, modifications of basal metabolic rate (23) and intestinal malabsorption. However, these factors could also be the effect and not the cause of the reductions in total mass seen in the studies. Calculating the impact of altitude alone on weight loss, therefore, cannot be limited to observation of the energy balance (24). Other factors such as increased stress or cold could also be related to this phenomenon (25) although the scientific evidence on this topic is scarce.

Although weight loss was consistent among all studies included in the review, changes in body composition followed different distribution patterns in the studies. Lean mass and fat mass loss as a unique finding were reported by five and six studies respectively. Several factors can explain the inconsistency in these results: a) it is well known that different methods of assessment of body composition report different results (26); b) time between the last day at altitude and assessment of body composition varied between studies, reaching even ten days in some cases (21); and c) studies included in the review were heterogenous regarding the time spent at altitude, distribution of altitudes reached during the expedition, number of subjects participating in the study and altitude reported during the stay, as can be seen in table II. The studies included in the review consistently reported reductions in total mass, fat mass and fat free mass. However, the role of altitude alone in this finding remains unknown as participants were subject to high energy expenditure together with decreased intakes during the mountaineering activities. Furthermore, none of the studies included a proper sedentary control group that would allow for a direct comparison. Moreover, previous research performed at similar altitudes but without indulging in physical activity during the stay reported no changes in body composition (27), a finding that puts on doubt the real influence of altitude alone on body composition changes reported during the stays. Absolute values for changes in total mass, fat mass and lean mass were reported (Table III) because most of the studies did not provide relative values and they could not be calculated. Therefore, caution is advised when interpreting these results as the same absolute change in mass in two subjects with different total mass would have a different impact. As the studies included in the review reported different durations of exposure (Table II), knowing whether weight decreases linearly with time would be of interest. However, participants varied their altitude, amount of physical activity and energy intake during the stays. Therefore, these confounding factors would influence the results of the possible association.

The assessment of the quality of the studies included in the review reported homogenous results for all studies (six to eight out of 14 points in the NIH score for observational studies). These results, as seen in table I, suggest that the studies included were of average quality according to this scale.

The results obtained in this systematic review show consistently that high altitude expeditions result in changes in the body composition. These results should be taken into account in order to design strategies that would prevent the reported findings: a) nutritional strategies that aim for counteracting the negative energy balance seen at altitudes could reduce weight loss (28); b) the palatability of food plays an important role when designing nutritional interventions for high altitude expeditions and easy to prepare and energy rich food should be the mainstay during mountaineering activities at high altitudes (29); and c) correct hydration has also an important role as it prevents water weight loss (30).

Simulated altitude techniques are becoming increasingly common in different types of interventions trying to evaluate effects of altitude stays (31). Hypobaric chamber interventions could be the best available option to investigate the effects of altitude as an isolated factor due to their laboratory setting and the possibility of controlling each one of the known variables that can potentially affect body composition during altitude stays (32). However, it is not known whether these methods can imitate the combination of conditionings normally found at altitudes. Indeed, one of the studies that met the inclusion criteria for duration and altitude was not included in the qualitative analysis as it was performed in a hypobaric chamber (22), thus raising several concerns as to whether this setting would completely imitate the conditions found at high altitudes (energy expenditure, physical activity, basal metabolic rate, etc.). There is insufficient data to support whether this method is valid for imitating altitude stay conditions in a laboratory setting. As to field research, studies should be more science-oriented in order to assess the confounding factors seen in previous research and help to establish strategies that would limit the effects of altitude stays on body composition.

This systematic review included studies above 4,000 m because this is the altitude (or above) at which the base camps of the highest mountains of the world are normally located. These criteria were chosen in order to guarantee the inclusion of studies performed only at very high altitudes. Also, 14 days was chosen as a minimal stay time in order to guarantee the appearance of at least some adaptations to altitude during a longitudinal follow-up. If these two criteria were to be changed, the list of the included studies would be affected greatly as many studies performed on lower altitudes would be included. Therefore, the results obtained in this review cannot be extrapolated to conditions different than those stated in the inclusion and exclusion criteria.

The current systematic review excluded non-English and non-Spanish publications; therefore, a possible language bias could appear. The main limitation of this systematic review is the incomplete data provided by the range of heterogeneous studies analyzed during the review: sample sizes were small, body composition assessment differed between studies and length of stays together with reported altitudes varied substantially. Finally, the amount of time between the end of the altitude stays and assessment of body composition was not equal in all studies, thus potentially affecting the results. In conclusion, research with better methodological design is needed in order to further study the subject.

## CONCLUSIONS

Mountaineering stays of at least 14 days of duration at altitudes above 4,000 m result in changes in body composition that are associated to reductions in total mass, fat mass and lean mass. The impact of altitude alone on these findings remains unknown due to the incomplete data provided by the range of heterogenous studies included in the review. Future research should have better methodological design and should include control groups. Interventions aimed at preventing and treating body composition changes associated to altitude stays should also be developed.

## CONFLICT OF INTERESTS

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.



## REFERENCES

1. Cohen JE, Small C, Earth L-D. Hypsographic demography: the distribution of human population by altitude. Vol. 95. Applied Physical Sciences; 1998.
2. Swenson ER, Maggiorini M, Mongovin S, Gibbs JSR, Greve I, Mairbäurl H, et al. Pathogenesis of high-altitude pulmonary edema: inflammation is not an etiologic factor. JAMA 2002;287(17):2228-35.
3. Jensen JD, Vincent AL. altitude illness, cerebral syndromes, high altitude cerebral edema (HACE). StatPearls: StatPearls Publishing; 2018.
4. Johnson TS, Rock PB. Acute mountain sickness. N Engl J Med 1988;319(13):841-5.
5. Hornbein TF, Townes BD, Schoene RB, Sutton JR, Houston CS. The cost to the central nervous system of climbing to extremely high altitude. N Engl J Med 1989;321(25):1714-9.
6. Harirchi I, Arvin A, Vash JH, Zafarmand V, Conway G. Frostbite: incidence and predisposing factors in mountaineers. Br J Sports Med

2005;39(12):898-901;discussion 901.
7. Westerterp KR, Meijer EP, Rubbens M, Robach P, Richalet JP. Operation Everest III: energy and water balance. Pflugers Arch 2000;439(4):483-8.
8. Boyer SJ, Blume FD. Weight loss and changes in body composition at high altitude. J Appl Physiol 1984;57(5):1580-5.
9. Duren DL, Sherwood RJ, Czerwinski SA, Lee M, Choh AC, Siervogel RM, et al. Body composition methods: comparisons and interpretation. J Diabetes Sci Technol 2008;2(6):1139-46.
10. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA Statement. PLoS Med 2009;6(7):e1000097.
11. National Heart, Lung, and Blood Institute (NHLBI). Study Quality Assessment Tools. Cited Jan 8th, 2019. Available from: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools
12. Guilland JC, Klepping J. Nutritional alterations at high altitude in man. Eur J Appl Physiol Occup Physiol 1985;54(5):517-23.
13. Kayser B, Narici M, Milesi S, Grassi B, Cerretelli P. Body composition and maximum alactic anaerobic performance during a one month stay at high altitude. Int J Sports Med 1993;14(5):244-7.
14. Pulfrey SM, Jones PJ. Energy expenditure and requirement while climbing above 6,000 m. J Appl Physiol 1996;81(3):1306-11.
15. Reynolds RD, Lickteig JA, Deuster PA, Howard MP, Conway JM, Pietersma A, et al. Energy metabolism increases and regional body fat decreases while regional muscle mass is spared in humans climbing Mt. Everest. J Nutr 1999;129(7):1307-14.
16. Westerterp KR, Kayser B, Brouns F, Herry JP, Saris WH. Energy expenditure climbing Mt. Everest. J Appl Physiol 1992;73(5):1815-9.
17. Westerterp KR, Kayser B, Wouters L, Le Trong JL, Richalet JP. Energy balance at high altitude of 6,542 m. J Appl Physiol 1994;77(2):862-6.
18. Wandrag L, Siervo M, Riley HL, Khosravi M, Fernández BO, Leckstrom CA, et al. Does hypoxia play a role in the development of sarcopenia in humans? Mechanistic insights from the Caudwell Xtreme Everest Expedition. Redox Biol 2017;13:60-8.
19. Zamboni M, Armellini F, Turcato E, Robbi R, Micciolo R, Todesco T, et al. Effect of altitude on body composition during mountaineering

expeditions: interrelationships with changes in dietary habits. Ann Nutr Metab 1996;40(6):315-24.
20. Sergi G, Imoscopi A, Sarti S, Perissinotto E, Coin A, Inelmen EM, et al. Changes in total body and limb composition and muscle strength after a 6-8 weeks sojourn at extreme altitude (5000-8000 m). J Sports Med Phys Fitness 2010;50(4):450-5.
21. Wagner DR. Body composition and hematological changes following ascents of Mt. Aconcagua and Mt. Everest. Aviat Space Environ Med 2010;81(11):1045-8.
22. Rose MS, Houston CS, Fulco CS, Coates G, Sutton JR, Cymerman A. Operation Everest. II: nutrition and body composition. J Appl Physiol 1988;65(6):2545-51.
23. Hill NE, Stacey MJ, Woods DR. Energy at high altitude. JR Army Med Corps 2011;157(1):43-8.
24. Kechijan D. Optimizing nutrition for performance at altitude: a literature review. J Spec Oper Med 2011;11(1):12-7.
25. Burtscher M. Re: "Increased cytokines at high altitude: lack of effect of ibuprofen on acute mountain sickness, physiological variables, or cytokine levels" by Lundeberg, et al. (High Alt Med Biol 2018 19:249-258). High Alt Med Biol 2018;19(3):303.
26. Wingo BC, Barry VG, Ellis AC, Gower BA. Comparison of segmental body composition estimated by bioelectrical impedance analysis and dual-energy X-ray absorptiometry. Clin Nutr ESPEN 2018;28:141-7.
27. Ermolao A, Bergamin M, Rossi AC, Carbonare LD, Zaccaria M. Cardiopulmonary response and body composition changes after prolonged high altitude exposure in women. High Alt Med Biol 2011;12(4):357-69.
28. Wing-Gaia LS. Nutritional strategies for the preservation of fat free mass at high altitude. Nutrients 2014;6(2):665-81.
29. Aeberli I, Erb A, Spliethoff K, Meier D, Götze O, Frühauf H, et al. Disturbed eating at high altitude: influence of food preferences, acute mountain sickness and satiation hormones. Eur J Nutr 2013;52(2):625-35.
30. Ladd E, Shea KM, Bagley P, Auerbach PS, Pirrotta EA, Wang E, et al. Hydration status as a predictor of high-altitude mountaineering

performance. Cureus 2016;8(12):e918.
31. Lizamore CA, Hamlin MJ. The use of simulated altitude techniques for beneficial cardiovascular health outcomes in nonathletic, sedentary, and clinical populations: a literature review. High Alt Med Biol 2017;18(4):305-21.
32. Draper N, Hellemans J. Real and simulated altitude training and performance. In: Current Issues in Sports and Exercise Medicine. InTech; 2013.

**Table I**. Assessment of the studies included in the review with the National Institutes of Health tool for observational studies

| Study | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Boyer and Blume (1984)** | Yes | Yes | NA | NR | No | Yes | Yes | Yes | Yes | Yes | Yes | No | NA | No | 8/14 |
| **Guilland and Klepping. (1985)** | Yes | Yes | NA | No | No | Yes | Yes | NA | Yes | Yes | Yes | No | NA | No | 7/14 |
| **Kayser et al. (1993)** | Yes | Yes | NA | NR | Yes | NA | No | No | Yes | Yes | Yes | No | NA | No | 6/14 |
| **Pulfrey and Jones (1996)** | Yes | Yes | NA | NR | Yes | NA | Yes | No | No | Yes | Yes | No | NA | No | 6/14 |
| **Reynolds et al. (1999)** | Yes | Yes | NA | No | No | Yes | Yes | Yes | No | Yes | Yes | No | NA | No | 8/14 |
| **Sergi et al. (2010)** | Yes | Yes | NA | NR | No | No | Yes | Yes | No | Yes | Yes | No | NA | No | 6/14 |
| **Wagner (2010)** | Yes | Yes | NA | NA | Yes | Yes | Yes | Yes | No | Yes | Yes | No | NA | No | 8/14 |
| **Wandrag et al. (2017)** | Yes | Yes | NA | NR | Yes | No | Yes | Yes | No | Yes | Yes | No | NA | No | 7/14 |
| **Westerterp et al. (1992)** | Yes | Yes | NA | NR | Yes | No | Yes | Yes | Yes | Yes | Yes | No | NA | No | 7/14 |
| **Westerterp et al. (1994)** | Yes | Yes | NA | NR | Yes | Yes | Yes | Yes | No | Yes | Yes | No | NA | No | 8/14 |
| **Zamboni et al. (1996)** | Yes | Yes | NA | NR | Yes | Yes | Yes | Yes | No | Yes | Yes | No | NA | No | 8/14 |

NA: not applicable; NR: not reported.

**Table II.** Characteristics of the studies included in the qualitative analysis

| Study | Type of study | Number of participants | Reported altitude (meters) | Duration of exposure (days) | Tool for evaluation of body composition | Outcome |
|---|---|---|---|---|---|---|
| **Boyer and Blume (1984)** | Observational, longitudinal | 13 | 5300-8848 | 45 | Anthropometry | Fat mass<br>Fat free mass<br>Body mass<br>% Fat |
| **Guilland and Klepping (1985)** | Observational, longitudinal | 4 | 4800-7102 | 16 | Anthropometry | Fat mass<br>Fat free mass<br>Body mass<br>% Fat |
| **Kayser et al. (1993)** | Observational, longitudinal | 8 | 4200-5050 | 28 | Anthropometry | Fat free mass<br>Body mass<br>% Fat |
| **Pulfrey and Jones (1996)** | Observational, longitudinal | 6 | 4000-8000 | 40 | Anthropometry | Fat mass<br>Fat free mass<br>Body mass<br>% Fat |
| **Reynolds et al. (1999)** | Observational, longitudinal | 10 | 5300-8848 | 36 | Anthropometry | Fat free mass<br>Body mass<br>% Fat |
| **Sergi et al. (2010)** | Observational, longitudinal | 8 | 5000-8000 | 53 | Dual Energy X-Ray Absorptiometry | Fat mass<br>Fat free mass<br>Body mass<br>% Fat |
| **Wagner (2010)** | Observational, longitudinal | 1 | 4240-8848 | 50 | Air displacement plethysmography | Fat mass<br>Fat free mass<br>Body mass<br>% Fat |
| **Wandrag et al. (2017)** | Observational, longitudinal | 14 | 5300-8848 | 32 | Anthropometry and Bioelectrical impedance | Fat mass<br>Fat free mass<br>Body mass<br>% Fat |
| **Westerterp et al. (1992)** | Observational, longitudinal. | 5 | 5000-8848 | 31 | Anthropometry | Fat mass<br>Fat free mass<br>Body mass<br>% Fat |
| **Westerterp et al. (1994)** | Observational, longitudinal | 10 | 4000-6542 | 21 | Anthropometry | Fat mass<br>Fat free mass<br>Body mass<br>% Fat |
| **Zamboni et al. (1996)** | Observational, longitudinal | 12 | 5000-7546 | 16 | Bioelectrical impedance<br>Anthropometry | Fat mass<br>Fat free mass<br>Body mass<br>% Fat |

**Table III.** Effects reported in the studies included in the systematic review. Numerical results are expressed as means.

| Study | Effects reported |
|---|---|
| **Boyer and Blume (1984)** | Significant reductions in total mass (-4.4 kg), and percentage of body fat (-2.5%) |
| **Guilland and Klepping (1985)** | Significant reductions in total mass (-4.7 kg), percentage of body fat (-6.8%) and fat mass (-2.9 kg) |
| **Kayser et al. (1993)** | Significant reductions in total mass (-2.6 kg) and lean mass (number not reported) |
| **Pulfrey and Jones (1996)** | Significant reductions in total mass (-3.7 kg), lean mass (-1.9 kg) and fat mass (-0.9 kg) |
| **Reynolds et al. (1999)** | Significant reductions in total mass (-3 kg) |
| **Sergi et al. (2010)** | Significant reductions in total mass (-3 kg) and lean mass (-2.4 kg) |
| **Wagner (2010)** | Significant reductions in total mass (-4.5 kg), percentage of body fat (-7.1%) and fat mass (number not reported) |
| **Wandrag et al. (2017)** | Significant reductions in total mass (-4.3 kg), lean mass (-3.5 kg) and fat mass (-1.2 kg) |
| **Westerterp et al. (1992)** | Significant reductions in total mass (number not reported), lean mass (-0.8 kg) and fat mass (-1.4 kg) |
| **Westerterp et al. (1994)** | Significant reductions in total mass (-4.9 kg), percentage of body fat (-4.3%) and fat mass (-3.5 kg) |
| **Zamboni et al. (1996)** | Significant reductions in total mass (-3.5 kg) |

Numerical results are expressed as means.

Fig. 1. Flow chart of the study selection process.