SHORT REPORT

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Does Regular Physical Activity generally Reduce Basal Energy Expenditure? Arguments against an Alleged Paradigm Change. A Short Report

Verringert regelmäßige körperliche Aktivität generell den Grundumsatz? Argumente gegen einen vermeintlichen Paradigmenwechsel. Ein Kurzbericht

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Summary

- **Careau et al.** recently published a paper entitled "Energy compensation and adiposity in humans" in the journal Current Biology. They evaluated measurements of total energy expenditure (TEE), basal energy expenditure (BEE) and activity energy expenditure (AEE) saved in a large data collection.
- **Based on an overall negative correlation** between BEE and AEE in a large group of subjects varying in sex, age and body mass they suggest that intense physical activity generally reduces BEE. There was "controlling for sex, age, and body composition".
- **But surprisingly the authors** do not present values per kg body mass despite comparing subjects with a large variation in this quantity. Data published in former publications by one of the coauthors allow calculating daily kcal/kg from means.
- **This indicates that low BEE** accompanied by high AEE was caused by a smaller body mass in physically active subjects.

Zusammenfassung

- **Careau et al.** haben kürzlich einen Artikel mit dem Titel "Energy compensation and adiposity in humans" in Current Biology veröffentlicht. Sie werteten Messungen des Gesamtenergieumsatzes (TEE), Grundumsatzes (BEE) und Aktivitätsumsatzes (AEE) aus einer großen Datensammlung aus.
- **Basierend auf einer insgesamt negativen Korrelation** zwischen BEE und AEE in einer großen heterogenen (Geschlecht, Alter, AEE) Personengruppe schlussfolgern sie, dass intensive körperliche Aktivität allgemein den BEE verringert. Einflüsse von „Geschlecht, Alter und Köperzusammensetzung wurden kontrolliert".
- **Aber überraschenderweise zeigen die Autoren** keine Werte bezogen auf kg Körpermasse, obwohl sie Werte von Personen mit einer großen Streubreite dieser Größe vergleichen. In früheren Veröffentlichungen eines Koautors ließ sich der tägliche Umsatz in kcal/kg aus Mittelwerten berechnen.
- **Das Ergebnis war:** Eine geringere Körpermasse bei aktiven Personen war offensichtlich die Ursache des niedrigen BEE bei zugleich hohem AEE.

KEY WORDS:
Sports, Physical Training, Nutrition, Body Mass, Weight Reduction, Circadian Rhythm

SCHLÜSSELWÖRTER:
Sport, Training, Ernährung, Körpermasse, Gewichtsabnahme, Circadianer Rhythmus

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Introduction

Recently Careau et al. published a paper entitled "Energy compensation and adiposity in humans" in the journal Current Biology (5). They evaluated measurements of total energy expenditure (TEE), basal energy expenditure (BEE) and activity energy expenditure (AEE) saved in a large data base (14), which contains more than 8000 TEE and BEE values. Based on an overall negative correlation between BEE and AEE in a group of 1754 subjects varying in sex, age and body mass they suggest that intense physical activity reduces BEE and therefore cannot reduce fat mass. Similar concepts of energy compensation have been described in various studies for within-subject reactions (reviewed e. g. by Westerterp 2015 (17)), but can they be applied to single measurements in subjects with varying body mass? Obviously one factor influencing energy consumption is the mass of metabolizing tissue. Additionally, exercise modalities also affect body weight and body fat (9). And can the concept be applied to athletes (which was not done by the authors)? Regeneration of energy stores, repair of possible muscle and connecting tissue damages as well as training processes are probably not possible without an increase in the measured BEE. In any case, the article by Careau et al. raises a series of questions.

Concept of Energy Compensation

A search in Pubmed yields many articles for "energy compensation". Westerterp (18) presented a systematic evaluation of the concept. His review shows that "an exercise-induced increase in activity energy expenditure can be compensated by a reduction in resting energy expenditure (REE) and by a reduction in non-exercise physical activity, especially at a negative energy balance." Additionally he suggests an increase in exercise efficiency by training in formerly untrained subjects; this is possible when complicated movements have been learned. Unfortunately, the definition of REE is not uniform. Westerterp and also Careau et al. assume that it is equal to BEE. According to Blasco Redondo et al. (2), however, unlike BEE, REE is not determined in fasting subjects and therefore includes the energy consumption for utilization of food.

Methods of Careau et al.

The authors evaluated the world-wide collection of TEE (doubly labelled water method) and BEE (indirect calorimetry) measurements in the International Atomic Energy Agency DLW database (14) performed from 1981 to 2017. Only 1754 healthy adult subjects (> 18 years old) were included. Interestingly not only pregnant, lactating, or diseased subjects were excluded, but also "subjects undergoing intense physical activity including professional sports training". To exclude the thermic effect of food (estimated as 10% of TEE), activity energy expenditure (AEE) was calculated as 0.9*TEE – BEE and the physical activity level PAL as PAL = TEE/BEE.

Average PAL was 1.74 ± 0.27SD (range: 0.76 – 3.30), 90% of the observations were between 1.35 and 2.18 PAL. To test the mutually exclusive predictions arising from the energy management models, they used multiple linear regressions with TEE as the dependent variable and sex, age, fat free mass FFM, fat mass FM, and BEE as independent variables.

Results of Careau et al.

The most interesting and problematic result is shown in figure 2, in which "Activity energy expenditure(AEE; MJ·d^{-1}) is presented as a function of age (y), fat free mass (FFM, in kg, square-root transformed), fat mass (FM, in kg, square-root transformed) and basal energy expenditure (BEE; MJ·d^{-1})." The values are presented for the whole body of subjects markedly differing in body mass, with some corrections for different body composition. BEE varies between 4 and 12 MJ/day, AEE between -2 and 10 MJ/day. Careau et al. calculated that "energy compensation by a typical human averages 28% due to reduced BEE; this suggests that only 72% of the extra calories we burn from additional activity translates into extra calories burned that day."

In figure 4, two measurements each in 68 old subjects (70-90 years) are shown, but separated by 7 years. There are similar but smaller changes in AEE relative to changes in BEE (less than 4 MJ compared to approximately 10 MJ in figure 2). This avoids comparisons among subjects with very different body mass. But intrapersonal changes in muscle (decreasing) and fat (increasing) mass with time especially because of aging may influence these results making the interpretation unsure.

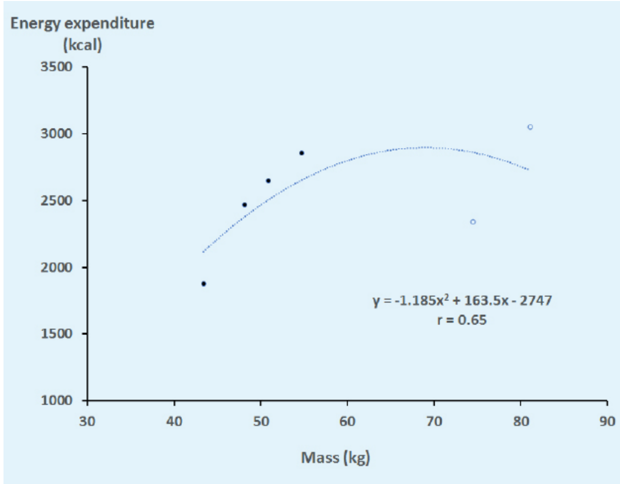

Figure 1

Daily energy expenditure in dependency on body mass. Mean values of physically active (Hadza and Bolivian, dots) and little active (North American, circles) males and females. From (3) with permission.

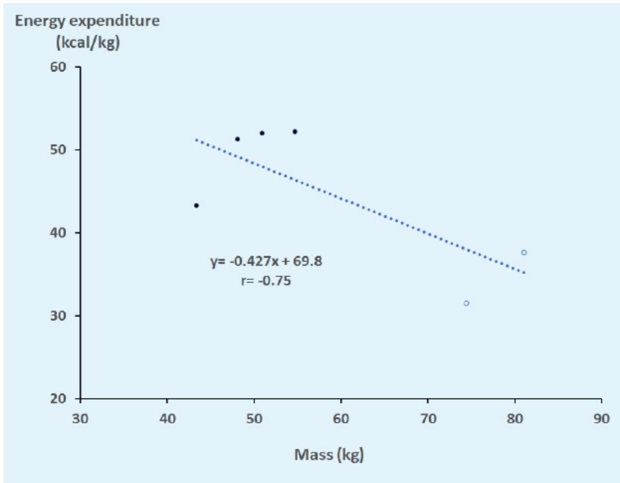

Figure 2

Daily energy expenditure per kg in dependency on body mass. Mean values of physically active (Hadza and Bolivian, dots) and little active (North Americans, circles) males and females. From (3) with permission.

Questions and Comments

Does the investigation by Careau et al. really support the concept of a lowered BEE resulting from increased AEE? The investigation and the interpretation of the data may cause various concerns.

1. Which is cause, which effect? In the decisive figure 2 of Careau's paper, BEE is presented on the x-axis and AEE on the y-axis. Every impartial reader perceives AEE as a function of BEE. Why do the authors suggest an inverse dependence?
2. The authors compare measurements of TEE over several days with one measurement of BEE in the morning. But BEE varies during 24 hours at least because of body temperature oscillation (6) ; there are several additional influencing factors (e.g. artificial light) which change during the day (10). Especially the excess post-exercise O_2 consumption (EPOC) may last more than 2 hours (15).
3. Smaller (and leaner) subjects with correspondingly low BEE are often more active than larger and/or obese people (17). ›

4. In figure 2 in Careau et al. some AEE expenditure values are low or even negative. At first glance this does not seem to make sense, but it may result from the calculation method. Possibly the usually measured morning value of BEE in awake subjects is higher than the daily average, since energy consumption is low during sleep. An interesting mechanism might also be that energy consumption is very low during negative exercise. Margaria (7) found that energy consumption in subjects running or walking on a treadmill was lowest descending compared to ascending or moving horizontally. The backgain is surely partly elastic (muscles, ligaments and tendons are initially stretched during ground contact and can shorten again without metabolic energy), but the hypothesis that metabolic processes are reversed during braking was already created by A. V. Hill (reviewed in (4)). ATPases splitting as well as synthesizing the molecule are frequent, e.g. in mitochondria (8). If somebody working in a high building ascends regularly by elevator but descends on the stairs, he also gets energy back into the braking muscles. However, the energy expenditure going downstairs is regularly larger than during horizontal stepping (0.05kcal per step for a 70-kg person), therefore no net energy gain is possible in this case (1).
5. Careau et al. present energy expenditure values per subject. They state that the data were controlled for sex, age, FFM and FM. But by this method they hide important influences. Why do they not simply present measured values? In our opinion, BEE and AEE have to be calculated also for kg body mass to avoid a confusing influence on the data when different subjects are compared. Careau, however, wrote in a personal communication: "Dividing by weight therefore introduces spurious artefacts, such as the illusion that greatly obese people have reduced metabolic rates, which misled the fields of energy balance for decades. Since the 1990s any serious investigators of these phenomena adjust for weight (and body composition) by using a regression model and calculating residuals - which is the approach we used to adjust our data for weight effects." In contrast to this statement, Westerterp (20) suggested in 2013 using AEE divided by body mass or by fat-free mass for comparisons between males and females because of the marked influence of these quantities on AEE. This is clearly demonstrated in the database used for the present article (figure 2 in (14)). In former publications Herman Pontzer (11) came to similar conclusions as in the present paper by Careau et al., obviously by not considering the dependence of energy turnover on body mass. We have evaluated the data in one of Pontzer`s papers – a comparison of energy consumption in slim and small African hunters and South American farmers, who were physically active many hours per day, with values in markedly heavier North American citizens (12). The authors observed no increased daily energy turnover in the first group when comparing the absolute values (kcal/day) and concluded that "average daily energy expenditure of traditional Hadza foragers was no different than that of Westerners after controlling for body size". But when we recalculated the data for kg body mass (only mean values, but probably not "corrected" were obtainable in Table 1 of the article), the values for the steadily moving and working subjects were higher than for the citizens using cars and elevators (figure 1 and 2 from (3)). This can be expected by simple reasoning.
6. BEE according to the definition used by Careau et al. is the minimum necessary for the resting empty-stomached body. Can it be reduced for a longer time without health problems? A study showing such a reduction after 40 weeks of hard physical training in previously sedentary subjects (19) seems to support this idea. However, in an investigation by Sjödin et al. a 16% higher REE was measured in top international-level cross-country skiers than in sedentary controls (13). They explained this observation by a high energy flux and overeating on the resting days, when measurements were performed. Also Speakman and Selman (15) communicate that REE is often (but not always) increased in athletes, partly caused by the large muscle mass and/or metabolic needs. Halsey (6) points out in the same way that excess postexercise oxygen consumption (EPOC) can elevate the metabolic rate above resting levels and BEE is underestimated. On the other hand he discusses that energy consumption for other organs than muscles may be reduced during exercise.
7. Many endurance athletes are lean in spite of eating a lot because the high total energy requirement (TER) due to high exercise energy expenditure (EEE) and additional energetic needs exceeds calory intake for some training periods. EEE might betwice as high as in the subjects in Careau's study with an EEE of approx. 76.5 kcal/kg per day or 7000 kcal for 91.8 kg in rowers (21); the Hazda and Bolivian subjects in (11) reached approx. 50 kcal/kg per day. Adequate daily nutrient intake hinders marked weight loss (16). Surprisingly Careau et al. (5) excluded the values of subjects performing intense physical training without presenting an explanation.
8. The number of 62 coauthors is very impressive but do they all support the interpretation in the article? The owner of the data (International Atomic Energy Agency) obliges every user to nominate all scientists who sampled the data as coauthors. One may doubt that many of them have checked or at least read the article before publication.

Conclusions

The hypothesis of a general reduction of BEE following intense exercise is not proven by this article. It has been convincingly described only in sedentary subjects after a hard training period. If the approach without considering body mass as in Careau's evaluation is correct, it should be applicable also to a comparison between mouse and elephant. A loss of body mass during physical training mainly depends on 2 factors: energy consumption by exercise and energy uptake by eating. For hard training athletes, who were excluded in Careau`s investigation, regeneration and filling of energy stores possibly do not allow energy compensation. ■

Conflict of Interest
The authors have no conflict of interest.

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ERWEITERTES ABSTRACT

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Does Regular Physical Activity generally Reduce Basal Energy Expenditure? Arguments against an Alleged Paradigm Change. A Short Report

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Inhalt

Die Veröffentlichung " Energy compensation and adiposity in humans" von Careau et al. in der Zeitschrift Current Biology (Curr Biol. 2021; 31: 4659-4666.e2) wurde analysiert. Die Autoren haben Messungen des Gesamtenergieumsatzes (TEE), Grundumsatzes (BEE) und Aktivitätsumsatzes (AEE) aus einer großen Datensammlung (Speakman et al.: Ann Nutr Metab. 2019; 75: 114-118) ausgewertet. Basierend auf einer insgesamt negativen Korrelation zwischen BEE und AEE in einer heterogenen (Geschlecht, Alter, AEE) Personengruppe schlussfolgern sie, dass intensive körperliche Aktivität allgemein den BEE verringert und deswegen keine Gewichtsabnahme verursacht (Konzept der Energiekompensation). Hinweise auf solche Effekte wurden in früheren Untersuchungen nach mehrwöchigem Training bei vorher untrainierten Personen gefunden. Aber ist das Konzept auch gültig für Querschnittsuntersuchungen und für regelmäßig trainierende Sportler?

Fragen und Kommentare

1. Die Autoren vergleichen Messungen von TEE über mehrere Tage mit Einzelmessungen von BEE am Morgen. Letztere erfasst weder circadiane Schwankungen noch zusätzliche Einflüsse (z. B. Nahrungsaufnahme, längerdauernde Umsatzerhöhung nach Arbeit).
2. Schlanke oder kleine Menschen mit entsprechend niedrigem BEE sind oft körperlich aktiver als große und/oder dicke Menschen.
3. In figure 2 in Careaus Veröffentlichung sind einige AEE-Werte nicht größer oder sogar niedriger als die zugehörigen BEE. Dies scheint Unsinn zu sein, aber es mag durch das Berechnungsverfahren verursacht oder sogar real sein. Beim Abwärtsgehen nehmen die abbremsenden Muskeln Energie auf, die elastisch oder vielleicht sogar zur Resynthese von ATP genutzt wird.
4. Careau et al. zeigen Energieverbräuche pro Person. BEE und AEE müssen aber auch für kg Körpermasse berechnet werden, wenn verschiedene Personen verglichen werden. Careau et al. behaupten, dass das Artefakte verursacht, aber andere Autoren gehen so vor. Herman Pontzer kommt in einer früheren Veröffentlichung (Hunter-gatherer energetics and human obesity. PLoS One. 2012; 7: e40503) zu denselben Schlüssen wie Careau et al., seine Mittelwerte erlauben den Vergleich zwischen kcal/Person und kcal/kg. Er findet keine Zunahme von kcal/Person bei leichten körperlich aktiven Menschen im Vergleich mit schweren wenig aktiven Nordamerikanern. Aber kcal/kg sind bei ersteren deutlich mehr!
5. BEE ist das nötige Umsatzminimum in Körperruhe. Er kann nach wochenlangem hartem Training von vorher nicht körperlich Aktiven eine Weile gesenkt sein. Bei Sportlern ist BEE aber im Vergleich dazu meist erhöht.
6. Viele Ausdauersportler sind trotz hoher Nahrungsaufnahme schlank wegen ihres großen Energiebedarfs. Der Umsatz kann doppelt so hoch wie in Careaus Studie werden. Diese Personengruppen wurden aber aus der Studie ausgeschlossen.

Schlussfolgerungen

Die Hypothese einer grundsätzlichen Verringerung von BEE nach intensiver Belastung wird durch Careaus Artikel nicht bewiesen. Eine Verringerung der Körpermasse durch Training hängt vor allem vom Energieverbrauch durch Arbeit und der Energieaufnahme durch Essen ab. Für hart trainierende, die in Careaus Analyse ausgeschlossen waren, erlauben Regeneration und das Auffüllen der Energiespeicher vermutlich keine Energiekompensation.

Schlussfolgerungen für die Praxis

1. Die Energiekompensation spielt bei Sportlern keine wesentliche Rolle. Ausreichende Energiezufuhr ist unverzichtbar.
2. Sondereffekte wie Gewichtmachen bei Ringern oder dauerhaft unzureichende Kalorienzufuhr bei manchen Sportarten können Schädigungen verursachen.

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