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Body Recomposition: Can Trained Individuals Build Muscle and Lose Fat at the Same Time?

Christopher Barakat, MS, ATC, CISSN,[1] Jeremy Pearson, MS,[1]
Guillermo Escalante, DSc, MBA, ATC, CSCS, CISSN,[2] Bill Campbell, PhD, CSCS, FISSN,[3] and Eduardo O. De Souza, PhD[1]
[1]Department of Health Sciences and Human Performance, The University of Tampa, Tampa, Florida; [2]Department of Kinesiology, California State University, San Bernardino, California; and [3]Performance & Physique Enhancement Laboratory, University of South Florida, Tampa, Florida

ABSTRACT

Despite the lack of standardized terminology, building muscle and losing fat concomitantly has been referred to as body recomposition by practitioners. Although many suggest that this only occurs in untrained/novice and overweight/obese populations, there is a substantial amount of literature demonstrating this body recomposition phenomenon in resistance-trained individuals. Moreover, 2 key factors influencing these adaptations are progressive resistance training coupled with evidence-based nutritional strategies. This review examines some of the current literature demonstrating body recomposition in various trained populations, the aforementioned key factors, nontraining/nutrition variables (i.e., sleep, hormones), and potential limitations due to body composition assessments. In addition, this review points out the areas where more research is warranted.

Address correspondence to Dr. Eduardo O. De Souza, edesouza@ut.edu.

INTRODUCTION

A common goal among active individuals is to improve their body composition by increasing skeletal muscle mass and decreasing fat mass (FM). It is well understood that these positive body composition changes have a multitude of health benefits (2,45,66) and have also been shown to improve athletic performance (12,60). Among physique competitors (e.g., individuals who compete in bodybuilding, figure, bikini, etc.), increasing muscle and losing body fat is also of critical importance to be successful in their sport. Despite the lack of standardized terminology, practitioners have described this adaptive phenomenon in which muscle mass is gained and FM is lost concomitantly as body recomposition.

It is generally thought that body recomposition occurs mainly in both the untrained/novice and overweight/obese populations. When examining the literature, this dogma seems logical because training age and also the novelty of initiating a resistance training (RT) program have been shown to directly impact the rate of muscle mass accrual (30,49,67). Within RT programs, practitioners can manipulate training variables (e.g., intensity, volume, exercise selection, etc.) as a means to enhance the muscle hypertrophic stimulus. Moreover, aerobic exercise is commonly implemented within training regimens to decrease FM (5). In addition, research has shown that the combination of both RT and aerobic exercise (i.e., concurrent training) can be an effective approach to optimize body recomposition (5,57). Thus, practitioners, coaches, and trainers commonly recommend concurrent training for individuals aiming to gain muscle and lose fat (24). Most importantly, despite the zeitgeist that well-trained individuals cannot gain muscle mass and lose fat simultaneously, there have been many chronic randomized controlled trials

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conducted in resistance-trained individuals that have demonstrated body recomposition (3,13,16,21,36,52,62,72).

In addition, dietary intake (i.e., energy balance, macronutrients, etc.) has been shown to influence body composition alone (6,11,23,25,28,31,54). Moreover, when combined with RT, body recomposition is potentiated to a greater degree (3,13,21). For example, protein intake is commonly manipulated among individuals seeking to maximize RT outcomes. There is evidence exhibiting recomposition effects when individuals are engaged in RT and are consuming a high dietary protein intake (i.e., >2.0 g/kg/d) (3,13,21). Interestingly, there are also data demonstrating that reductions in FM can occur in well-trained subjects with hypercaloric intakes, specifically when the surplus is due to an increase in protein (13,22). Collectively, those studies suggest that evidence-based nutritional strategies can further enhance body recomposition in trained individuals.

Physique competitors carefully manipulate both their training and nutritional programs to maximize muscle mass and decrease FM to present their most aesthetic physique. During the "off-season," they strive to accumulate as much muscle mass as possible, while minimizing FM gained in a hypercaloric state (24). However, most case studies on physique competitors through contest preparation do not demonstrate a recomposition effect (33,48,56). During this phase, competitors restrict their caloric intake, and increase energy expenditure to attain extremely low levels of body fat. This hypoenergetic state has been shown to negatively impact many variables that can affect body recomposition such as sleep, hormones, and metabolism (35,46,69,71). Therefore, these intense physical demands significantly stress the body and make recomposition difficult for this population.

When analyzing the current literature demonstrating body recomposition in trained individuals, it is important to consider contextual differences between studies (i.e., body composition assessments, training design, duration, nutritional control, etc.) and their potential to impact the outcomes (Tables 1–4). Therefore, the purpose of this review is to discuss the existing literature that has reported body recomposition among resistance-trained individuals. Second, we will address the contrasting results reported in the literature among a majority of competitive physique athletes during contest preparation.

ESTIMATING BODY COMPOSITION WITH DIFFERENT ASSESSMENTS

To draw conclusions from each study's results, it is important to understand the methods for assessing body composition, their strengths, weaknesses, and reliability. These assessments rely on different assumptions and vary based on how many compartments it divides an individual's total mass (i.e., 4C, 3C, 2C). Typically, body composition is divided into bone content, lean mass (i.e., muscle, connective tissue, internal organs, etc.), and FM. In addition, it is important to consider that there can be a significant variability/error rate depending on the mode of body composition assessment (8,22,68). Furthermore, external factors (for example, hydration status [intracellular versus extracellular], nutritional status [fasted versus fed], etc.) can influence the accuracy of how these assessments quantify fat-free mass (FFM) and FM. It is also important to note that precisely quantifying gains in skeletal muscle tissue can be difficult due to its composition (i.e., ∼75% water, ∼15–25% protein, ∼2–3% glycogen, and ∼5% intramuscular triglycerides) (19,22,34). Therefore, the goal of this section is to provide a simple overview of the body composition methods used in the studies, presented in Tables 2–4.

The 4-compartment model (4C) that has been considered the gold-standard assessment divides the body into FM, water, bone mineral content, and residual content (63,68). Moreover, the 4C model also allows for estimation of protein content (74). However, it is costly and very time-consuming because 4C uses a variety of laboratorial assessments. Two of these laboratory assessments include magnetic-resonance imaging (MRI) and computed tomography. Recently, the combination of different tools (i.e., DEXA + BIA) has been used to quantify total body volume into 4C.

Dual-energy x-ray absorptiometry (DEXA) is a 3-compartment model commonly used to monitor and assess changes in body composition. It can distinguish between bone mineral content, FFM, and FM. Furthermore, it can compartmentalize different regions of the body (i.e., trunk, leg, arm), but is unable to discern between specific muscle groups (e.g., quadriceps/hamstrings, biceps/triceps, etc.) (22). A recent validation study demonstrated a lower error rate using DEXA for measuring intraindividual, concomitant changes in FFM and FM (68). In addition, newer models have been shown to have strong test-retest intraclass correlation coefficients while estimating FFM during whole-body scans (e.g., >0.99) (32). The standard error rate when comparing the criterion MRI to DEXA for estimating body fat percentage is ∼1.6%. It is important to note that some of the recomposition results demonstrated in the training/nutrition literature may be within the standard error rate. Thus, these results must be taken with caution because the magnitude of change in these studies may be due to inherent variation from the measurement method.

Body composition can also be separated into 2 compartments (e.g., FFM and FM) using BodPod, skinfold calipers, bioelectrical impedance, underwater weighing, and ultrasound techniques. Air-displacement plethysmography (BodPod) is an apparatus that estimates body composition based on the inverse relationship between volume and pressure. It measures the amount of air displaced by an individual's body considering thoracic gas volume. A few studies have shown slight discrepancies in accurately determining body fat percentages (range = 1.8–3.6 %BF) when examining air-displacement plethysmography (39,43). However, BodPod does seem to have a strong test-retest reliability (e.g., >0.99) (70). In addition, a recent

Table 1
Summary of advantages and disadvantages using various techniques for measuring body composition

Method	Advantages	Disadvantages
4C	It is considered the gold standard One of the best methods for estimating body composition It enables the calculation of FFM hydration It measures total body water	It is time-consuming It is not accessible for most practitioners and coaches
DEXA	3-compartment model: Able to measure FFM, FM, and bone mineral content Able to measure a region of interest specifically in extremities	Nutritional/hydration status can significantly alter body composition and decrease accuracy Limited use for measuring baseline FM or longitudinal changes in FM with weight loss because measurements are known to be biased by body size (thickness)
BodPod	Could provide longitudinal data on both FFM and FM mass because its accuracy is less likely to be affected by changes in fatness.	Cannot provide regional data and can only distinguish between FM and FFM (i.e., bone, muscle, connective tissue). It assumes fixed densities of FM and FFM
Hydrostatic weighing	Valid estimate for body density	Expensive, not easily accessible Uncomfortable It assumes fixed densities of FM and FFM
A-mode ultrasound	Capable of regional and segmental measurements Valid in the hands of an experienced technician Portability	Depending on technician, there can be a high possibility of intrarater reliability Most of the equations/formulas were based on caliper validation

4C = four compartments; DEXA = dual-energy x-ray absorptiometry; FFM = fat-free mass; FM = fat mass.

study comparing DEXA to BodPod in collegiate hockey players demonstrated that BodPod significantly overestimated FFM (2.93 ± 2.06 kg) and underestimated FM (3.27 ± 1.92 kg) (18). Regarding the training/nutrition studies using BodPod at both baseline and posttesting, the absolute values should be taken with caution. However, given the relatively high test-retest reliability for BodPod, more confidence can be given regarding the reported delta changes in FM and FFM.

Finally, another assessment to examine changes in body composition is A-mode ultrasonography. Specifically, this technique can measure muscle thickness and subcutaneous fat. Recently, this method has also been used to calculate total body FFM, FM, and body fat percentage in conjunction with the 7-site Jackson-Pollock formula (9). This assessment has been reported to be similar to DEXA for estimates of body composition (9,51). Importantly, training/nutrition studies using A-mode ultrasonography need to consider intra-individual variability when performing body composition assessments.

Due to the potential limitations for each assessment, practitioners need to be aware that minor changes in body composition demonstrated with these tools may be due to inherent variability and/or covariates that were not quantified (e.g., hydration and nutritional status). With that said, when these methods are appropriately used and strictly standardized, there is a stronger likelihood that the results observed are accurate and reliable.

TRAINING STATUS

It is well accepted that training status significantly impacts the rate of progress in body composition. Novice trainees tend to experience greater muscular adaptations compared to advanced lifters. For example, Cribb et al. (16) reported significant gains in FFM (+5 kg) and reductions in FM (−1.4 kg) in a group of recreationally trained individuals over 10 weeks. However, Antonio et al. (4) reported that highly trained subjects gained 1.9 kg of FFM and did not demonstrate significant reductions in FM over an 8-week period. Many high-level athletes often take time away from their training regimen (i.e., off-season) or have a period with substantially less work performed (i.e., detraining). This detraining period will likely lead to a temporary reduction in training status, performance, and body composition profile. However, once training resumes, these individuals typically regain their body composition adaptations rapidly (47). For example, Zemski et al. (76) reported significant gains in FFM (+1.8 kg) and reductions

Table 2
Summary of study designs that have demonstrated recomposition with resistance training without nutrition reported in trained individuals

Study	Training status/demographic	Study design	Training intervention	BC assessment	Nutrition	Conclusions
Alcaraz et al. (1)	Resistance-trained men with at least 1 y of RT experience and can produce a force equal to twice their body mass during an isometric squat	Counterbalanced repeated-measures design. Participants were randomly assigned to high-resistance circuit (HRC) training or Traditional strength training (TST). 8-wk intervention	Both groups performed 6RM sets to failure for 6 total compound and isolation exercises 3 d/wk	DEXA	NR	Both groups increased FFM, and lost a non-significant amount of FM. HRC (FFM +1.5,[a] FM −1.1) TST (FFM + 1.2,[a] FM −0.8)
Colquhoun et al. (15)	RT college males with ≥6 mo experience. 1RM squat: BM ratio-low frequency 1.7 high frequency 1.6 1RM bench: BM ratio-low frequency 1.3 high frequency 1.2 1RM deadlift: BM ratio-low frequency 2.0 high frequency 2.0	Counterbalanced, parallel-groups repeated-measures design. Participants were randomly assigned to low frequency (3×/wk) or high frequency (6×/wk). 6-wk intervention	Daily undulating periodization program designed to target the powerlifts (squat, bench press, and deadlift) while equating intensity and volume	A-mode ultrasound	NR	Both groups increased FFM, and lost a non-significant amount of FM. Low frequency (FFM +1.7,[a] FM −0.3) High frequency (FFM +2.6,[a] FM −0.1)
Wilborn et al. (72)	NCAA Division III female basketball players (at least 1 y RT experience)	Parallel-group repeated-measures design. Participants were randomly assigned to whey (W) or casein (C). 8-wk training period	Full-body undulating periodized program 4 d/wk. Sport-specific conditioning 3 d/wk	DEXA	NR	Both groups increased FFM and lost FM. W (FFM +1.5[a], FM −1.3[a]) C (FFM +1.4[a], FM −0.6[a])
Yue et al. (75)	Recreationally trained men with average 3 y RT experience 1RM squat: BM ratio LV-HF 1.3 ± 0.3 HV-LF 1.1 ± 0.1 1RM bench: BM ratio LV-HF 1.0 ± 0.2 HV-LF 0.9 ± 0.2	Parallel-group repeated-measures design. Participants were randomly assigned to low training volume-high frequency (LV-HF) or High training volume-low frequency group (HV-LF)	6-wk hypertrophy/strength program	BodPod	NR	Both groups increased FFM, and lost a non-significant amount of FM. LV-HF (FFM +1.2,[a] FM −0.6) HV-LF (FFM +1.4,[a] FM −2.4)

[a] Statistical significance.

BM = body mass; DEXA = dual-energy x-ray absorptiometry; RT = resistance training; FFM = fat-free mass; FM = fat mass; HP = high protein intake; HV-LF = high volume-low frequency; NP = normal protein intake; NR = not recorded; PRO = protein intake; 1RM = one repetition maximum.

Table 3
Summary of study designs that have demonstrated recomposition with resistance training and nutrition data provided in trained individuals

Study	Training status/ demographic	Study design	Training intervention	BC assessment	Nutrition	Conclusions
Antonio et al. (3)	Resistance-trained men and women who had been weight training regularly Avg Normal pro: 2.4 ± 1.7 High pro: 4.9 ± 4.1	Parallel-group repeated-measures design. Participants were randomly assigned to normal protein (NP) or high protein (HP) groups. 8-wk heavy resistance training program	Hypertrophy-oriented upper and lower split routine program 5 d/wk	BodPod	NP group maintained the same dietary habits (2.3 g PRO/kg/d) HP group consumed (3.4 g PRO/kg/d) Total calories-NP: 2,119 HP: 2,614	Both groups increased FFM and lost FM. NP (FFM +1.5^{a}, FM −0.3^{a}) HP (FFM +1.5^{a}, FM −1.6^{a})
Antonio et al. (4)	Resistance-trained men and women who had been weight training regularly (8.9 ± 6.7 y and an average of 8.5 ± 3.3 h per wk)	Counterbalanced-group repeated-measures design. Participants were randomly assigned to NP or HP groups. Subjects performed training outside of laboratory and reported total volume load at baseline and posttesting. 8-wk intervention	Participants exercised outside of the laboratory and were asked to track their total volume load	BodPod	NP group maintained the same dietary habits (1.8 g PRO/kg/d) HP group consumed 4.4 g PRO/kg/d. Total Cal- NP: 2,052 HP: 2,835	Both groups increased FFM and reduced body fat percentage to a non-significant degree. The HP group lost a non-significant amount of FM and the NP group gained a trivial amount of FM. NP (FFM +1.3, FM +0.3) HP (FFM +1.9, FM −0.2)
Campbell et al. (13)	Aspiring female physique athletes able to deadlift 1.5× BM and ≥3 mo RT 1RM squat: BM ratio-High protein group 1.1 Low protein group 1.2 1RM deadlift: BM ratio-high protein group 1.4 Low protein group 1.6	Parallel-group repeated-measures design. Participants were randomly assigned to HP or low protein (LP). 8-wk intervention	Hypertrophy-oriented upper and lower split routine program. 4 d/wk	A-mode ultrasound	LP group consumed (0.9 g PRO/kg/d) HP group consumed (2.5 g PRO/kg/d) Total Cal- HP: 1,839 LP: 1,416	Both groups increased FFM, however only the HP group lost a significant amount of FM. HP (FFM +2.1^{a}, FM −1.1^{a}) LP (FFM +0.6^{a}, FM −0.8)

(continued)

Table 3
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Cribb et al. (16)	Recreational bodybuilders with at least 2 y of RT experience 1RM squat: BM ratio-Both groups 0.9 ± 0.1 1RM bench: BM ratio-whey group 1.0 ± 0.1 Casein group 1.1 ± 0.1	Parallel-group repeated-measures design. Participants were randomly assigned to whey protein (W) or casein protein (C) groups. 10-wk training period	Linear progressive overload program. Designed for maximizing strength and hypertrophy was divided into 3 phases; preparatory (70–75% of 1RM), overload phase-1 (80–85% of 1RM), and overload phase-2 (90–95% of 1RM). Upper and lower split routine	DEXA	Both groups on average consumed 2.1 g PRO/kg/d during the study.	Both groups increased FFM. However, only the W group lost FM. W (FFM +5.0,^{a} FM −1.4^{a}) C (FFM +0.8,^{a} FM +0.1)
Haun et al. (21)	Resistance-trained young men with minimum estimated 1.5 × BM squat 3RM squat: BM ratio-1.6 3RM bench: BM ratio-1.2	Parallel-group repeated-measures design. Participants were partitioned to maltodextrin (M), whey protein (WP), or graded whey protein (GWP) groups. 6-wk training period	Linear progressive overload program. Full-body 3×/wk. Sets would increase each wk but repetitions remained at a goal of 10 per exercise.	DEXA	All groups aimed for a 500 calorie surplus and 1.6 g/PRO/kg/d during the first wk of the study. The groups on average consumed 2.2 g/PRO/kg/d throughout the study.	All groups increased FFM but only the W and GWP lost FM. M (FFM +2.3,^{a} FM +0.2) WP (FFM +1.7,^{a} FM −0.7^{a}) GWP (FFM +2.9,^{a} FM −1.0^{a})
Kreipke et al. (36)	Resistance-trained young men (≥1 y training in the squat, bench, and deadlift) 1RM squat: BM ratio-both groups 1.6 1RM bench: BM ratio-Placebo 1.2 Preworkout 1.3 1RM deadlift: BM ratio-Placebo 2.0 Preworkout 2.1	Parallel-group repeated-measures design. Participants were randomly assigned to placebo (PL) or Preworkout supplement (SUP) 4-wk training period	4 d/wk progressive, strength-oriented powerlifting regimen. 5 × 5 and 3 × 10 of compound exercises performed to volitional fatigue	DEXA	No differences in PRO or caloric intake. Avg PRO intake: 2.1 g/kg/d	Both groups increased FFM but only the PL group lost a significant amount of FM. PL (FFM +1.1,^{a} FM −0.7^{a}) SUP (FFM +1.3,^{a} FM −0.2)

Table 3
(continued)

Slater et al. (62)	Elite male water polo and rowers Avg RT experience PL: 7.1 ± 1.7 HMB: 7.4 ± 2.0 trHMB: 6.9 ± 0.8	Parallel-group repeated-measures design. Participants were randomly assigned to placebo (PL), HMB, or time released HMB (trHMB) groups. 6-wk training period	Full-body strength-oriented program composed of mainly compound exercises with 24–32 sets per session	DEXA	All groups on average consumed 2.4 g PRO/kg/d and increased mean energy intake 224 kJ/kg/d during the study	All groups gained FFM. However, reductions in FM were non-significant. PL (LBM +0.9,[a] FM −0.4) HMB (LBM +1.2,[a] FM −1.0) trHMB (LBM +3.5,[a] FM −2.5)
Rauch et al. (52)	NCAA Division II female volleyball players 1RM squat: BM ratio 1.1	Parallel-group repeated-measures design. Participants were randomly assigned to optimal training load (OTL) or Progressive velocity-based training (PVBT)	7-wk (3 d/wk) power-oriented full-body program	DEXA	No differences in PRO or caloric intake. Avg PRO intake: 1.6 g/kg/d	Both groups increased FFM and lost FM. OTL (FFM +2.7,[a] FM −2.7[a]) PVBT (FFM +2.7,[a] FM −2.1[a])

[a] Statistical significance.

BM = body mass; DEXA = dual-energy x-ray absorptiometry; FFM = fat-free mass; FM = fat mass; HP = high protein intake; NP = normal protein intake; PRO = protein intake; 1RM = one repetition maximum; OTL = optimal training load.

Table 4
Summary of case studies that investigate body composition changes in response to exercise, nutrition, and supplementation of competitive physique athletes

Study	Competitor demographic	Resistance training	Aerobic	BC assessment	Nutrition supplements	Conclusions
Halliday et al. (20)	27-y-old drug-free amateur female figure competitor 20-wk prep + 20-wk recovery	Prep: 4–5 d/wk High-volume program training each muscle group 2–3×/wk Recovery: 3–4 d/wk high-volume program	Prep: (10–30) min HIIT 1–2 d/wk and (45–120 min) aerobic exercise 1 d/wk Recovery: (10–30 min) HIIT 1–2 d/wk and (45–60 min) aerobic exercise 1 d/wk	DEXA	≥2.2 g/kg PRO daily throughout prep and recovery Supplements used: whey and casein protein and 5 g/d of creatine monohydrate	Body fat decreased from 15.1% (8.3 kg) at baseline to 8.6% (4.3 kg) one wk out of competition. FFM was maintained at 44.3 kg throughout 20-wk prep 20-wk postcomp showed BF% returned to baseline at 14.8%.
Kistler et al. (33)	26-y-old drug-free, amateur male bodybuilder with 10 y RT experience 26-wk prep	5 d/wk 60–90 min sessions Each muscle group trained 2×/wk Day 1: 3–8 reps Day 2: 8–15 reps	Beginning contest prep, two 40-min sessions of high-intensity interval training (HIIT) per wk. End of contest prep, four 60-min sessions of HIIT and two 30-min sessions of low-intensity steady-state (LISS) per wk	DEXA	250 g PRO daily for all prep Supplements used: 30 g BCAA, 3 g HMB, 2 g fish oil, 5 g creatine mono, 6 g beta alanine, multivitamin	FFM decreased 6.6 kg FM decreased 10.4 kg
Pardue et al. (48)	21-y-old drug-free, amateur male bodybuilder with 8 y RT experience 32-wk prep + 20-wk recovery	5–6 d/wk Each muscle group trained 2×/wk Variety of repetition ranges (4–25 repetitions) and intensities	No aerobic exercise was performed at baseline, but cardio was incrementally increased until reaching a weekly load of two 20-min HIIT sessions and four 30-min medium-intensity steady state (MISS) sessions.	BodPod and DEXA	At baseline, the competitor consumed 3,860 cal (28% protein [3.2 g/kg], 52% carbohydrate [5.9 g/kg], 20% fat [1.0 g/kg]) End of prep, the competitor consumed 1,724 kilocalories (52% protein [2.9 g/kg], 19% carbohydrate [1.1 g/kg], 29% fat [0.7 g/kg]) Supplements used: whey protein, BCAA, creatine monohydrate, beta-alanine, and preworkout	Prep: BF% decreased from 13.4 to 9.6% recovery: BF% increased to 17.2%

Table 4
(continued)

Petrizzo et al. (50)	29-y-old drug-free amateur female figure competitor with 8-y RT experience 32-wk prep	Phase 1: 4–5 d/wk for the first 22 wk; phase 2: 6 d/wk for the final 10 wk) High-volume program performing 3× sets to failure each exercise	Phase 1 (20–60): min HIIT 3 d/wk Phase 2 (30–40): min HIIT 4 d/wk	DEXA	>3.2 g/kg PRO daily throughout prep Supplements used: BCAA, whey protein, beta alanine, citrulline malate, alpha-hydroxyisocaproic acid, creatine monohydrate, vitamin B-6	FFM increased 0.7 kg FM decreased 8.0 kg
Rohrig et al. (55)	24-y-old drug-free female competitor with 5-y RT experience 24-wk prep	5 d/wk Each muscle group trained 2×/wk; one with moderate intensity (60–80% 1RM) and volume and one with high intensity (85% + 1RM) and lower volume	Weekly adjustments of HIIT and MISS based on discretion of coach. At end of prep 185 min of MISS with HIIT 3d/wk	Hydrostatic weighing	≥2.0 g/kg PRO daily throughout prep Supplements used: creatine monohydrate, fish oil, and multivitamin	BF% was reduced from 30.45 to 15.85% FFM increased 1.3 kg FM decreased 11.4 kg
Rossow et al. (56)	27-y-old drug-free professional male bodybuilder with 2 y pro status 24-wk prep + 24-wk recovery	4 d/wk Each muscle group trained 2×/wk during the 48-wk	Prep: 1 d/wk of HIIT and 1 d/wk of LISS Recovery: 1 d/wk of HIIT	BodPod and DEXA	Prep period macros: ∼36% PRO, ∼36% carbohydrate (CHO), and ∼28% fat for 5 d/wk and ∼30% PRO, ∼48% CHO, and ∼22% fat for 2 d/wk. Recovery period macros: ∼25–30% PRO, 35–40% CHO, and 30% to 35% fat. Supplements used: whey protein and 5 g/d of creatine monohydrate	Prep: (FFM −2.8 kg) BF% decreased from 14.8 to 4.5% Recovery: (FFM −0.2 kg) BF% increased to 14.6%

BF% = body fat percentage; CHO = carbohydrate intake; RT = resistance training; DEXA = dual-energy x-ray absorptiometry; FFM = fat-free mass; FM = fat mass; HIIT = high-intensity interval training; LISS = low-intensity steady state; MISS = medium-intensity steady state; Prep = weeks leading into a competition; PRO = protein intake; Recovery = weeks after a competition; 1RM = one repetition maximum.

in FM (−2.2 kg) in elite rugby players after detraining for 4 weeks and then returning for an 11-week high-volume, high-intensity training program during their preseason.

When exploring the literature on physique athletes, most of the data are demonstrated in case studies examining competitors during contest preparation (For details, Table 4). Contrary to what has been observed in the aforementioned trained populations, most physique athlete case studies do not demonstrate a body recomposition effect (33,48,56). This is likely due to the extreme demands of this sport (i.e., energy restriction, high energy expenditure, severely low body fat, negative hormonal adaptations, poor sleep, etc.), which will be discussed later in this review. Interestingly, there is some conflicting evidence demonstrating body recomposition in female physique competitors during their contest preparation phase (50,55). One potential explanation for the differences between males and females might be associated with hormonal profile. For example, significant reductions in testosterone levels have been observed in males while in a hypoenergetic state, dieting for competition purposes (26,44,48,64). Therefore, the data on physique athletes are difficult to reconcile due to the unique hypoenergetic demands of their sport in season when compared to other trained populations. Although training status/age seems to impact the magnitude of changes in FFM and FM, more research is warranted to understand how training status can impact body recomposition over time in different trained populations.

TRAINING PRACTICES IN STUDIES WITH TRAINED INDIVIDUALS DEMONSTRATING BODY RECOMPOSITION

Several studies among trained individuals have reported body recomposition where nutritional intake was not reported or was similar between the interventions (1,36,52,62,72,75). For example, Alcaraz et al. (1) recruited participants who were able to produce a force equal to twice their body mass during an isometric squat at the beginning of the intervention. The subjects performed 8 weeks of either a high-resistance circuit (HRC) or a traditional strength training (TST) program. Both groups performed 3–6 supervised sets of 6 exercises (3 compound and 3 isolation) using a 6 repetition maximum (RM) to failure. The HRC group used a 35-second interset recovery between exercises and performed the exercises in circuit fashion, whereas the TST group rested 3 minutes between each set of each exercise before moving to the next exercise. Only the HRC group significantly decreased body fat percentage by −1.5%, whereas the TST group did not (−1.1%). However, both groups demonstrated a significant increase in FFM of 1.5 and 1.2 kg, respectively. In addition, in another investigation, researchers examined recreationally trained males with 3 years of RT experience. This six-week study randomized subjects into either a low volume-high frequency (LV-HF) group where participants RT 4 days per week or a high volume-low frequency (HV-LF) group where participants RT 2 days per week (75). All participants were instructed not to alter their normal nutritional habits. However, the researchers did not report nutritional intake between the groups. Both groups performed the same weekly volume, but the RT volume differed between the sessions. Regarding body composition, both LV-HF and HV-LF groups significantly gained FFM (1.2 and 1.4 kg, respectively). However, the reductions in FM only reached statistical significance in the HV-LF group (−2.4 kg) compared to LV-HF (−0.6 kg). In another recent study, Colquhoun et al. (15) investigated the effects of training frequency (3×/week versus 6×/week) using a volume-matched design in well-trained subjects undergoing a powerlifting program. Both groups gained a significant amount of FFM (3×/week: 1.7 kg, 6×/week: 2.6 kg) and although they both lost FM (−0.3 and −0.1 kg, respectively), these reductions were not statistically significant.

Collectively, these studies indicate that body recomposition can occur in trained individuals using a variety of RT programs that are geared to develop muscular strength and hypertrophy. In addition, adjusting nutritional intake is common in individuals attempting to maximize RT gains in strength and hypertrophy (54). In the next section, we will discuss RT studies that either monitored, controlled, or manipulated the subjects' nutritional approach.

NUTRITIONAL INFLUENCE ON BODY RECOMPOSITION WHEN COUPLED WITH RESISTANCE TRAINING

The combination of RT and specific nutritional strategies can significantly impact training performance (52), recovery (7), and body composition (14,28,61). Generally, caloric deficits are prescribed for individuals seeking to lose FM and caloric surpluses are recommended for those seeking to maximize muscle mass accrual (23,54,61,73). Although this is common practice, there is evidence that challenges this approach and suggests there may be alternative strategies to improve body composition (3,4,40,42). For instance, there are data showing significant gains in FFM and reductions in FM while in a caloric surplus (21). In addition, significant body recomposition has been demonstrated in hypocaloric studies (40,42). Recently, Slater et al. (61) questioned the necessity of a hypercaloric intake to maximize skeletal muscle hypertrophy in conjunction with RT. The mechanisms that may explain the body recomposition phenomena are not well understood. For example, the precise energy cost of skeletal muscle growth is not fully known. In addition, we are unsure how the magnitude of energy supply, specifically endogenous sources (i.e., internal fat stores/body fat levels) and exogenous fuel (i.e., diet), pertain to this process (61). With that said, body composition changes seem to be more complex than energy balance alone because research has shown that different nutritional strategies (i.e., high-protein diets, hypocaloric diets, etc.) may elicit body recomposition (13,21,40).

In fact, RT studies have demonstrated body recomposition in which nutrition was controlled and/or manipulated. More specifically, some of these studies increased the participant's caloric intake, primarily from dietary protein (3,13,21). For example, Antonio et al. (3) investigated the effects of a very high-protein diet (HP 3.4 g/kg) compared to a "normal protein" diet (NP 2.3 g/kg) on body composition in well-trained men and women in conjunction with heavy RT. The participants underwent an RT program (upper-lower split) 5 days per week for 8 weeks and both groups gained a significant, yet equal amount of FFM (1.5 kg). Interestingly, the HP group, which was consuming an additional ~495 calories per day, lost significantly more FM than the NP group (−1.6 versus −0.3 kg). The authors highlighted the large interindividual variability, which is important for practitioners to be aware of. For instance, in both groups, some subjects gained up to 7 kg of FFM while losing 4 kg of FM concomitantly. However, some subjects actually lost FFM and gained FM. Their data suggest that ~70% of subjects improve their overall body composition when implementing high-protein diets.

Body recomposition effects of a larger magnitude that reached statistical significance were observed by Haun et al. (21) in their extreme-volume RT study that investigated the effects of graded whey protein (WP) supplementation in well-trained males. Subjects underwent full-body RT sessions 3 times per week, and volume was progressed from 10 weekly sets per exercise to 32 sets over the 6-week intervention. Participants were randomized into 3 groups: maltodextrin group (MALTO) consuming 30 g per day, WP group receiving 25 g per day, and graded WP (GWP) group receiving an additional 25 g WP each week during the 6-week study (25–150 g WP/day). Furthermore, all groups were instructed by a registered dietician to consume specific macronutrients guidelines equating to a ~500 calorie surplus. All groups demonstrated a significant increase in FFM from pre to post (MALTO: 2.35 kg, WP: 1.22 kg, GWP: 2.93 kg). However, only the WP and GWP groups displayed a significant reduction in FM simultaneously (−0.65 and −1.0 kg, respectively). Although the WP and GWP groups were using different post-workout nutrition interventions, when looking at their daily protein intake, no significant differences were observed (2.3 versus 2.2 g/kg, respectively). Notably, although the MALTO group was not receiving WP supplementation, their relative daily protein intake (2.3 g/kg) was not different compared to the WP and GWP groups. These results may suggest potential benefits of specific nutrient timing (i.e., post-workout) versus total daily intakes in highly trained individuals performing extreme volume progressions. However, nutrient timing and its effects on body recomposition in trained populations warrant further investigations.

Additional evidence from Campbell et al. (13) reported similar positive effects on body composition when aspiring female physique athletes increased their total calorie intake (~250 kcal) from dietary protein alone. These subjects were split into 2 groups, low protein (LP 0.9 g/kg) and high protein (HP 2.5 g/kg), while undergoing an upper-lower RT split, 4×/week. The HP group demonstrated a significant body recomposition effect, gaining 2.1 kg FFM and losing −1.1 kg of FM despite consuming an additional 423 kcals daily. However, the LP group only gained a statistically significant, yet relatively small amount of FFM (0.6 kg) and did not demonstrate significant reductions in FM (−0.8 kg). When evaluating the individual data from this study, all subjects in the HP group gained FFM, whereas some subjects (3 of 9) in the LP group actually lost FFM. These data further support the importance of dietary protein intake for those undergoing RT and trying to improve body composition. However, body recomposition effects of even larger magnitudes have been reported with a moderate protein intake and a more balanced nutritional approach (52). The variability between studies makes it difficult for researchers, coaches, and practitioners to make evidence-based suggestions as we continue to investigate which approach is the most advantageous for trained individuals.

In another study, Rauch et al. (50) reported significant body recomposition in female collegiate volleyball players undergoing 7 weeks of power-oriented, full-body RT with similar relative lower-body strength. All dietary information was recorded and analyzed to quantify total and relative (i.e., g/kg) calories and macronutrient intake. Moreover, all participants consumed 25 grams of WP immediately after each exercise session, consumed the same relative quantity of protein per day (1.6 g/kg), and consumed a similar caloric intake throughout the study. Participants were assigned to either an optimal training load (OTL) where participants worked at velocities that maximized power output, or a progressive velocity-based training (PVBT) group, where participants worked at slower velocities (geared at strength), the first training block, and then progressed to OTL velocities, the last training block. The investigators reported that the OTL group increased 2.7 kg of lean body mass and lost 2.7 kg of FM, whereas the PVBT group gained 2.7 kg of lean body mass and lost 2.1 kg of FM. These substantial recomposition findings may have been amplified due to multiple factors. For example, the starting body fat percentage in these volleyball players was higher compared to the leaner, aspiring female physique competitors in the aforementioned study (~29 versus ~22%). This may have influenced the greater reductions in FM and gains in lean body mass. In addition, these athletes received nutritional guidance from a sports nutritionist/registered dietician. Finally, this investigation was conducted during their conditioning phase (i.e., off-season) after a detraining period.

Taken together, these reports document the process of body recomposition with moderate to high dietary protein intakes coupled with progressive RT across a wide spectrum of trained populations. Moreover, having higher levels of body fat may affect the magnitude of body recomposition because these fat stores may provide endogenous energy to support muscle mass accrual (61). However, the impact of initial body fat levels, training status, RT programs, and nutritional intake on body recomposition are not yet fully elucidated and warrants further investigation.

NONTRAINING/NUTRITION-RELATED FACTORS THAT MAY INFLUENCE BODY RECOMPOSITION

Although it is not fully understood, additional factors such as sleep (i.e., quality and quantity), stress hormones (e.g., cortisol), androgenic hormones (e.g., testosterone), and metabolic rate may influence changes in body composition (38,46,53,71). Unfortunately, many training and nutrition studies do not take into account these important covariates. However, when examining the body of literature that has investigated the effects of these factors on body composition, it is clear they can impact how each individual is responding to the interventions.

For example, Wang et al. (71) examined the effects of sleep restriction (~1 hour reduction, 5×/week) on weight loss outcomes in overweight adults in a hypocaloric environment. They demonstrated that both groups in an equated caloric deficit lost a similar amount of total body weight (−3.2 kg). However, when analyzing the percentage of FFM within total mass lost, the sleep-restricted group lost significantly more FFM than they did FM (84.8 versus 16.9%), respectively. However, their counterparts who were not sleep-restricted better preserved FFM and lost a significant amount of FM (17.3 versus 80.7%) of the total mass lost, respectively. It is important to note that these subjects were not undergoing RT. They also observed that the sleep-restricted group had a significant increase in ghrelin (71). Ghrelin is commonly referred to as the "hunger hormone" and has been shown to increase the likelihood of weight regain (specifically fat) and is one component (of many) why some individuals fail to maintain their weight loss (65,69).

Additional data investigating sleep deprivation have demonstrated negative effects on multiple athletic performance variables and recovery capabilities (17,41,53). For example, Reilly and Piercy (53) observed significant reductions in strength-endurance performance and total volume load on compound exercises such as the bench press, deadlift, and leg press when subjects were in a sleep-restricted state. Furthermore, they reported that the subject's rating of perceived exertion was significantly greater when performing the same RT task in a sleep-deprived state. These negative effects are important to note because training volume is a critical variable for muscle hypertrophy (59).

Sleep deprivation is also associated with negative hormonal adaptations through the hypothalamic-pituitary-adrenal axis –leading to an increase in cortisol, glucose, and insulin, and a decrease in testosterone, adiponectin, and growth hormone (27,37,38). This dysregulation seems to create an "anti" body recomposition environment, where building muscle mass and losing FM would be less likely. More specifically, in athletic populations, hypocaloric intakes and significant reductions in body weight and FM have been shown to negatively impact testosterone (48,64,69). For example, Bhasin et al. (10) have demonstrated that there is a direct relationship between serum testosterone levels and gains in FFM. This may partially explain why the case studies in natural bodybuilders have demonstrated a loss in FFM while preparing for their competition despite their RT and high protein intake. More recently, a study also demonstrated that sleep restriction had a detrimental acute effect on myofibrillar protein synthesis rates, which may be associated with loss of muscle mass negatively impacting body composition. This study also reported that protein synthesis rates can be maintained by performing high-intensity exercise even under the sleep-restriction scenario (58).

Although studies have focused on describing the negative effects of sleep restriction on several different parameters including body composition, there is a paucity of data on how improving sleep quality would specifically impact body composition. To date, only one study investigated the effects of a sleep intervention combined with chronic RT on body composition. Jabekk et al. (29), designed a very practical study in which 23 untrained individuals were analyzed after undergoing a sleep education intervention on how to improve both sleep quantity and quality (ExS group) compared to exercise only (Ex group). Both groups performed a full-body workout routine for 10 weeks, and body composition was assessed using DEXA. After 10 weeks, both groups similarly increased FFM (ExS: 1.7 kg and Ex: 1.3 kg). However, only ExS significantly reduced FM, whereas Ex did not (ExS: −1.8 and Ex 0.8 kg). Interestingly, sleep questionnaire scores were not different from pretesting to posttesting between groups.

Although the last study suggests that optimizing sleep may potentiate body recomposition in people RT, it was conducted in untrained individuals. Thus, the impact sleep quality and quantity may have on body recomposition in trained individuals needs to be determined. In addition, when investigating many of the previous studies referenced in this review, these nontraining/nutrition factors were not monitored or controlled in trained populations. Therefore, one may argue they may have impacted the results of the studies and partially explain differences in the body recomposition outcomes between subjects and groups. However, more research is required to better understand if these negative outcomes in body composition can be prevented or minimized when trained participants have adequate sleep and a more favorable hormonal profile.

CONCLUSION

Despite the common belief that building muscle and losing fat at the same time is only plausible in novice/obese individuals, the literature provided supports that trained individuals can also experience body recomposition. Individuals' training status, the exercise interventions, and their baseline body composition can influence the magnitude of muscle gained and fat lost. Resistance training coupled with dietary strategies has been shown to augment this phenomenon. In addition, there seems to be confounding nontraining/nutrition variables such as sleep, hormones, and metabolism that can significantly influence these adaptations. Thus, coaches and practitioners must self-audit their current approach, determine how they can improve their training and nutritional regimen on an individual basis, and implement evidence-based strategies to optimize body recomposition.

PRACTICAL APPLICATIONS

The literature demonstrating a body recomposition effect consist of a highly heterogeneous set of designs, methods, and outcomes. These discrepancies in methodology make specific guidelines to optimize body recomposition difficult to reconcile. Nevertheless, the following recommendations can be drawn from the methods used and results reported within the studies discussed in this review.

- Implement a progressive RT regimen with a minimum of 3 sessions per week.
- Tracking rate of progress, and paying attention to performance and recovery can be important tools to appropriately adjust training over time.
- Consuming 2.6–3.5 g/kg of FFM may increase the likelihood or magnitude of recomposition (3,25,28,61).
- Protein supplements (i.e., whey and casein) may be used as a means to increase daily dietary protein intake as well as a tool to maximize muscle protein synthesis. This may be of greater importance postworkout as a means to maximize the recomposition effect (21).
- Prioritizing sleep quality and quantity may be an additional variable that can significantly impact changes in performance, recovery, and body composition (41,46,53,71).

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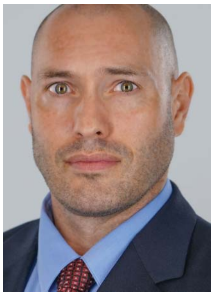
Christopher Barakat *is a human performance researcher at the University of Tampa and the owner of Competitive Breed LLC., specializing in bodybuilding/physique coaching.*

Jeremy Pearson *is a PhD student in the Applied Physiology Laboratory at The University of Kansas.*

Guillermo Escalante *is an associate professor of Kinesiology at California State University San Bernardino.*



Bill Campbell *is a professor of Exercise Science and the Director of the Performance and Physique Enhancement Laboratory at the University of South Florida.*

Eduardo O. De Souza *is an assistant professor in the Health Sciences and Human Performance Department at The University of Tampa.*

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