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CASE STUDY

Case Study: Body Composition Periodization in an Olympic-Level Female Middle-Distance Runner Over a 9-Year Career

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This case study features an Olympic-level female middle-distance runner implementing a science-based approach to body composition periodization. Data are emerging to suggest that it is not sustainable from a health and/or performance perspective to be at peak body composition year-round, so body composition needs to be strategically periodized. Anthropometric ($n = 44$), hematological, other health measures, and 1,500-m race performances ($n = 83$) were periodically assessed throughout a 9-year career. General preparation phase (September to April) featured the athlete at ~2–4% over ideal competition phase body weight (BW) and body fat (%), with optimal energy availability being prioritized. The competition body composition optimization phase (May to August) included creating an individualized time frame and caloric deficit with various feedback metrics (BW, performance, and hunger) to guide the process. There were significant seasonal fluctuations in anthropometric outcomes between phases (47.3 ± 0.8 vs. 48.3 ± 0.9 kg BW; 53.6 ± 7.8 vs. 61.6 ± 9.7 mm International Society for the Advancement of Kinanthropometry sum of 8 [So8] skinfolds; $p < .01$), and a significant correlation of decreasing So8 during the peak competition period over her career ($r = -.838$; $p = .018$). The range of body composition during the competition period was 46.0–48.0 kg BW and a So8 range was 42.0–55.9 mm. There were also significant positive correlations between slower 1,500-m race times and increasing So8 ($r = .437$; $p < .01$), estimated fat mass ($r = .445$; $p < .01$), and BW ($r = .511$; $p < .0001$). The athlete only had two career injuries. This case study demonstrates a body composition periodization approach that allowed for targeted peak yearly performances, which improved throughout her career, while maximizing training adaptation and long-term athlete health through optimal energy availability.

Keywords: anaerobic, anthropometrics, elite, energy availability, health, performance

Although the concept of training periodization has been developing over the last 70 years, the concept of nutrition and body composition periodization synched with training and competition demands is just emerging (Jeukendrup, 2017; Stellingwerff et al., 2007, 2011). However, beyond these collections of reviews highlighting theoretical approaches to nutritional and body composition periodization, there is little published primary data and no published longitudinal data in Olympic-level athletes.

To the author's knowledge, body composition periodization has not been previously defined, and thus is currently defined as "the strategic manipulation of energy intake and energy expenditure between various training phases to reach a targeted body composition range that is optimal for performance (e.g., peak power-to-weight ratio), while minimizing risk to short-term and long-term health." Even with a strong conceptual underpinning, very little scientific information exists on how to optimally implement interventions around body composition periodization throughout a given year, let alone over an entire career.

This case study will feature an Olympic-level female middle-distance runner implementing a science-based approach to provide a contextual framework for body composition periodization throughout a 9-year international career. To the author's knowledge, there is very limited normative data on Olympic-level female middle-distance anthropometrics (Deutz et al., 2000; Fleck, 1983), and beyond a few yearly case study reports in other sports, no existing data regarding yearly or career-long body composition periodization outcomes.

Interventions and Methods

Athlete and Case Study Background

This female White athlete (characteristics given in Table 1) has read, approved, and provided written permission for this publication, and the study has been approved by the University of Victoria Ethics Committee. Given that this was a 9-year longitudinal intervention, there was learning and refining throughout, which was based both on individually acquired data/metrics (as mentioned below), as well as emerging scientific literature to support the various interventions. Accordingly, the most contemporary studies are referenced throughout.

Body Composition, Blood Work, and Dual-Energy X-Ray Absorptiometry Assessments

Anthropometrics over the 9-year period were measured by the same Level I practitioner according to the 2006 International Society for the Advancement of Kinanthropometry (ISAK) protocols (Marfell-Jones et al., 2006). The practitioner's average technical error of measurements for all skinfolds was 5.7% and for all girths was 0.8%. Skinfolds were taken from triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh,

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and medial calf (for sum of 8 [So8] skinfold values), while measurements of arm, waist, gluteal, and mid-thigh circumference (girth) were conducted according to standard ISAK protocols. Body fat percentage (in %) was calculated as 0.1548 × (sum of triceps, subscapular, supraspinale, abdominal, thigh, calf) + 3.580 (Yuhasz, 1982). The lowest total error is represented in the So8 outcomes, as error is compounded in body fat percentage equations. Bone mineral density was assessed four times throughout her career—Lausanne, Switzerland (GE 10 Lunar iDXA), Victoria, Canada (GE Lunar Prodigy), and twice in Flagstaff, AZ (GE Lunar DPX-IQ)—by a trained technician using dual-energy X-ray absorptiometry.

Table 1 Performance, Physiological, Medical, and Training History Characteristics Over the 9-Year Analysis Period (2008–2016)

Parameter	
Age range during analysis period	27–35 years
No. of races over analysis period	132
No. of 1,500 m races over analysis period	83
No. of global championships (3 × finalist)	7
No. of major injuries over analysis period (9 years)	2
1,500 m PB (primary event)	4:05.08
No. of 1,500 m times within ~1% of PB	11
No. of seasons 1,500 m times within ~1% of PB	5 out of 9
Average VO_{2max} (ml/kg/min)	65.3 ± 2.4
Average whole-body BMD (g/cm^2)	1.065 ± 0.109
Average whole-body BMD *Z* score	0.7 ± 0.3
No. of missed menstrual cycles/year (2009–2013[a])	2.8 ± 0.8

Note. All data are presented as mean ± *SD*, unless noted with race times reported as min:s. Global championships include Olympic, World, and Commonwealth Games. Major injury counted as more than 1 week off of training. BM = body mass; BMD = bone mineral density; PB = personal best.
[a]The athlete was not on birth control during this period.

Dietary Interventions and Advice

General Preparation Body Composition Phase (September to April). This phase featured having the athlete ~2.1% (range of 0.5–5.8% across the years) over competition phase body mass and ~18% greater in body fat percentage (Figure 1; Table 2). General nutrition practices, with emphasis on contemporary nutrition recommendations (Stellingwerff et al., 2011) with weight stability and optimal energy availability (EA), were emphasized. Optimal EA is defined as adequate energy intake to cover the energy cost of exercise as well as optimal metabolic function and health (Mountjoy et al., 2014).

Competition Body Composition Optimization Phase (May to August). Several scientifically supported principles guided this phase, including:

a. A body composition assessment (ISAK) was completed ~3 months prior to competition season, and the outcomes were compared with the limited normative data (Deutz et al., 2000; Fleck, 1983) in elite female middle-distance runners to establish a "current" versus "goal" body composition target range (goal range of ISAK So8 of ~40–60 mm or ~8–12 body fat percentage range; Deutz et al., 2000; Fleck, 1983). Over several years, the goal body composition range (approximately ±1% of body weight [BW] or ±5% skinfolds) transitioned from normative data to individually developed data.
b. Deutz et al. (2000) demonstrated in elite female runners and gymnasts that the number of hours with energy deficits greater than 300 calories was positively associated with increases in body fat percentage ($r = .407$; $p < .001$); thus, a ~300 calorie deficient was targeted.

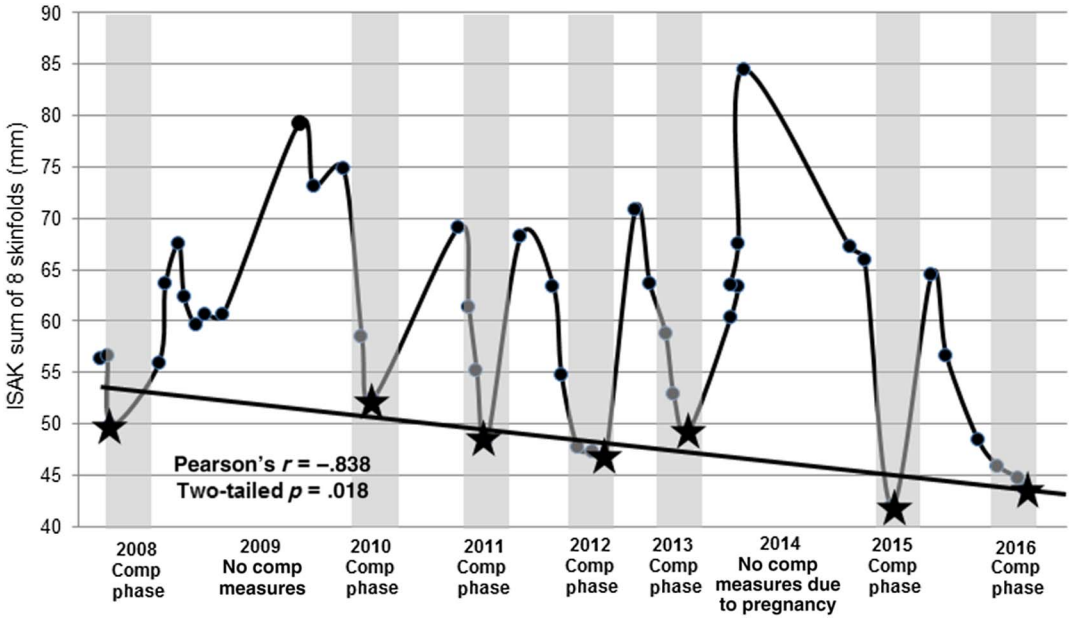

Figure 1 — Anthropometric data over a 9-year career (2008–2016; $n = 44$ measurements). ISAK sum of standard 8 skinfolds (in mm). Star indicates the lowest sum of 8 during each peak competition phase season. Gray zones indicate yearly competition phase (May to August, yearly). ISAK = International Society for the Advancement of Kinanthropometry; Comp = competition.

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Table 2 Anthropometric Comparisons Between Competition Phase and All Other Phases of Training Over the 9-Year Analysis Period (2008–2016)

Parameter	Competition phase ($n = 13$)	Noncompetition phase ($n = 31$)	% difference from competition p hase
Age (years)	29.6 ± 2.4	30.2 ± 2.7	−1.9
Body mass (kg)	47.3 ± 0.8	48.3 ± 0.9*	−2.1
Height (cm)	162 ± 0	162 ± 0	0.0
BMI	18.0 ± 0.3	18.5 ± 0.4*	−2.7
ISAK sum of 8 skinfolds (mm)	53.6 ± 7.8	61.6 ± 9.7*	−13.0
Body fat percentage (Yuhasz equation)	10.6 ± 1.2	12.9 ± 1.4*	−17.8
Predicted nonfat mass (mainly muscle, kg)	41.7 ± 0.4	42.1 ± 0.7*	−0.9
Predicted fat mass (kg)	5.6 ± 0.7	6.2 ± 0.8*	−10.6
Waist girth (cm)	65.4 ± 0.8	66.6 ± 1.2*	−1.8
Gluteal girth (cm)	79.3 ± 2.7	81.5 ± 1.4*	−2.7
Standing mid-thigh girth (cm)	46.3 ± 1.0	46.9 ± 1.4	−1.2
Calf girth (cm)	32.7 ± 0.7	32.8 ± 0.8	−0.2

Note. All data presented as mean ± *SD*. All measurements were made in the months of May, June, July, and August ($n = 13$). Out of competition phase measurements ($n = 31$). BMI = body mass index; ISAK = International Society for the Advancement of Kinanthropometry.
*Significant difference between competition phase versus noncompetition phase ($p < .01$).

c. An individualized time line (~6–8 weeks of duration) with weekly weight loss goal ranges was developed using a dynamic negative exponential plateauing weight loss simulation (Thomas et al., 2013). This approach was further supported with data in athletes showing that a slower weight reduction of ~0.7% BW loss/week is more effective for enhancing performance than a fast weight loss protocol (Garthe et al., 2011).

d. Finally, during the slight caloric deficit, the athlete aimed to increase daily protein intake (~2–2.5 g/kg BW/day) with optimal daily timing and distribution, with the aim to better maintain lean mass while decreasing fat mass (Mettler et al., 2010; Phillips, 2014).

Within this phase, athlete instructions were as pragmatic as possible to create a daily ~300 calorie deficit and included the following interventions, in order of implementation: (a) several days of dietary recording and/or an oral dietary interview to inform the athlete to minimize all calorically dense and less functional calories (e.g., fats, sweets); (b) a decrease in snacking and carbohydrate serving sizes on easy training days; (c) if required, purposely having smaller portion sizes that are mainly periodized to easy training days; and (d) if required, overnight fasted training and/or replacing a meal with just a protein supplement. A combination of photos representing the target caloric deficient along with education around food substitutions and serving sizes were implemented. For this case study athlete, generally only steps (a) and (b) outlined previously were required to create the deficit needed to achieve her body composition goals.

Practical metrics (mainly qualitatively collected through feedback) were collected and refined to provide feedback to the process, both within a given season and over subsequent years (setting achievable benchmarks from one season to inform the next season), that included: (a) morning voided body mass tracking ~3 times/week, (b) periodic body composition assessment (ISAK) every ~2–4 weeks, (c) satiety and mood state, (d) sleep quality, (e) training quality, (f) race performance outcomes, (g) illness and/or injury occurrence, and (h) menstrual cycle regularity. Accordingly, several years of data collection and analysis are required to establish feasible and individualized health and performance body composition ranges for a single athlete.

Analysis Approach

All data are reported as means ± *SD*. There is no 2014 data available, as the athlete was pregnant. Predicted fat mass (in kg) was derived from the calculated body fat percentage as a percentage of total BW, with predicted nonfat mass being the remaining difference of total BW. *F* testing showed samples of unequal variance, thus two-tailed *t* tests of unequal variance were performed. This athlete's smallest worthwhile effect was calculated as 0.3 × the coefficient of variation (1.7%; Hopkins, 2004) for all races during the competition phase ($n = 43$ races). All bivariate correlations completed as two-tailed Pearson's *r* with significance set to $p < .05$.

Observations and Outcomes

Performance, Physiological, Medical, and Anthropometric Parameters

Performance, physiological, medical, and training history characteristics over the 9-year analysis period are outlined in Table 1. Over four dual-energy X-ray absorptiometry scans spanning from 2009 to 2016, the athlete had a positive *Z* score for bone mineral density and an above-normal bone mineral density of 1.065 ± 0.109 g/cm^2 (Table 1). There were significant seasonal fluctuations in So8 as well as a correlation of a decreased So8 skinfolds during the peak competition period as the athlete matured over her career (Figure 1; $r = -.838$; $p = .018$). Several significant differences in anthropometric outcomes between the competition phase (May through August) were shown compared with the rest of the year (Table 2). The calculated smallest worthwhile effect in 1,500-m race time for this athlete was 1.26 s. The range of body composition parameters within the smallest worthwhile effect of the yearly best

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time (11 peak performances) was a BW range of 46.0–48.0 kg and a So8 range of 42.0–55.9 mm (9.2–10.9% body fat).

Anthropometric Associations With Performance

There was a significant negative correlation of improving 1,500-m race times throughout this entire analysis period ($r = -.304$; $p < .01$; e.g., 2008 average of 4:14.28 and 2016 average of 4:11.13). There were also significant positive correlations between slower 1,500-m race times and increasing So8 ($r = .437$; $p < .01$; Figure 2), increasing estimated fat mass ($r = .445$; $p < .01$), and increasing estimated fat-free mass ($r = .293$; $p = .025$). The strongest correlation was with lower total BW correlating with faster 1,500-m race performance ($r = .511$; $p < .0001$).

Discussion

This case study is the first longitudinal data in an Olympic-level female middle-distance runner showcasing annual and career body composition periodization coupled with performance and health outcomes. The overriding ethos was that it is not sustainable from a health and performance perspective to be at peak body composition year-round, so body composition needs to be strategically periodized. Although correlative in nature, this case study demonstrates a body composition periodization approach, coupled with ever improving anthropometric and performance outcomes at the peak competition period, over a 9-year career with only two injuries.

This athlete had a "low-risk" assessment for either Relative Energy Deficiency in Sport (RED-S) (Mountjoy et al., 2014) and the Female Athlete Triad (Joy et al., 2014) tools during the majority of the training year in the general preparation phase, and a low (RED-S tool) or moderate risk assessment (Triad tool) during the competition phases. Many of the health-based assessment parameters of both the RED-S and Triad tools can also impact on injury risk and rates. There are several explanations as to why a periodized body composition approach, which optimizes EA, may additionally minimize injury and illness risk. First, it appears that staying injury and illness free may directly increase an athlete's likelihood of satisfying their performance goals. A recent 5-year retrospective analysis in track and field athletes showed that the likelihood of achieving a performance goal decreased seven times in those who completed less than 80% of planned training weeks due to injury/illness (Raysmith & Drew, 2016). Female athletes have also been shown to have a ninefold higher odds of illness or injury incidence, and that low EA was predictive of athletes being seven times more likely to become ill at the Summer Olympics (Drew et al., 2017). Furthermore, a study in collegiate female athletes ($n = 239$) has shown that athletes with moderate to high Female Athlete Triad risk factors are two to four times more likely to sustain a bone injury, respectfully, than low-risk athletes (Tenforde et al., 2017). In the current 9-year case study, the athlete only had two injuries (missed training for >1 week) and only missed 2.8 ± 0.8 menstrual cycles/year (all missed cycles during competition phase), which satisfies the definition of eumenorrhea (Joy et al., 2014; Mountjoy et al., 2014). There are also links between optimal EA and iron status (Petkus et al., 2017), with this athlete having an average ferritin of 91 ± 36 μg/L, and only one bout of anemia throughout her career. Accordingly, this athlete had a myriad of indicators suggesting optimal EA for the majority of her training year and career, which fits with a very low career injury rate.

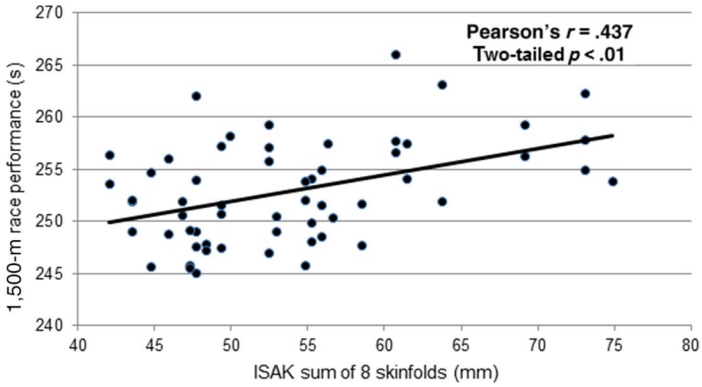

Figure 2 — Anthropometric data versus 1,500-m race performance over a 9-year career (2008–2016; $n = 53$ measurements). ISAK sum of standard 8 skinfolds (in mm). Comparison made with race time if anthropometric data within ±30 days of a competition. ISAK = International Society for the Advancement of Kinanthropometry.

A periodized body composition approach also may enhance long-term body composition outcomes (e.g., athlete leanness). Deutz et al. (2000), in one of the largest studies of elite female cohorts of gymnasts and runners ($n = 62$), examined energy balance and body composition outcomes. Interestingly, one of the findings was that the athlete cohort in the greatest daily hourly energy deficit (rhythmic gymnasts) actually had the highest body fat percentage (16.6%), while the athletes nearest to hourly and daily energy balance (middle-distance runners) had the lowest body fat percentage (12.1%). Therefore, instilling dietary habits to allow for optimal EA hourly and daily, as well as for the majority of the time (throughout general preparation phase), may be an important long-term factor in developing a leaner physique. Undeniably, as this athlete matured, she was significantly leaner (lower ISAK sum of 8) during each subsequent peak competition period (Figure 1), while concurrently increasing her estimated fat-free mass over her career ($r = .534$; $p < .001$). Interestingly, the author has observed that this progressive maturation of optimal body composition occurs in several other Olympic female distance runners with a "low-risk" RED-S assessment (unpublished observations from 2012 until 2016), demonstrating that body composition periodization optimization requires optimal EA and a multiyear/career approach. However, beyond the various purposeful dietary interventions pointed out, it should be noted that there are various other confounding factors that may contribute to body composition changes across various training phases. Some of these factors include training load differences (volume/intensity), injuries, altitude training camps, and recovery (nontraining) phases, most of which have been described in a recent systematic review ($n = 82$ studies) in endurance athletes (Heydenreich et al., 2017).

Another understudied aspect to a periodized body composition approach, which theoretically could be impactful, is long-term training adaptation when weight-dependent athletes train at a heavier mass during the general preparation phase, and then taper their weight back down during the competition period (Table 2). Bosco et al. demonstrated that when creating a prolonged training block in a hypergravity environment (by using ~10% of BW-weighted vests), there were significant performance increases in elite athletes in various neuromuscular tests (e.g., drop or vertical jumps) compared with control (Bosco, 1985; Bosco et al., 1986). It is important to note that both Bosco et al. papers only implemented a 3-week intervention, with the latter paper only doing hypergravity training 3–5 sessions/week. Therefore, being slightly heavier

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during the much longer 8-month general preparation phase (Table 2), where the athlete would take ~90,000 steps/week, would potentially create a greater neuromuscular and cardiovascular overload and increased stimulus for training adaptation, which can be maintained during the shorter competition phase when the athlete lowers BW and body fat percentage to realize peak performance. However, this theoretical mechanism requires future research to validate.

Obviously, many important running- and physiological performance-based metrics are BW-dependent (e.g., VO_{2max} in ml/kg/min, running economy in ml/kg/km, or power-to-weight ratio in W/kg). Correspondingly, as pointed in the results, various significant correlations were shown between lower BW and So8s (Figure 2) and 1,500-m race performance. This aligns well with the fact that ~80% of the metabolic cost of running is BW (Hoogkamer et al., 2017). It is also important to point out that there was an ideal range of peak body composition parameters that this athlete would aim for each season, and not a single BW or composition outcome. Obviously, at some point, a lower BW will result in muscle mass loss, subsequent to a decrease in the ability to generate power and speed and reduced performance outcomes.

Another aspect to this case study approach was the repeated measurements of the mid-thigh girth, which was, despite a 2.1% drop in BW, maintained ($p > .05$; Table 2) during the competition phase ($p > .05$; Table 2). Further analysis over the 9 years also showed continual increases in estimated fat-free mass (primarily muscle mass; $r = .829$; $p = .02$) during peak competitive season. It appears that an essential element in optimizing body composition during situations of nonoptimal EA (maintaining or even increasing lean muscle mass) is the macronutrient protein. Therefore, during periods of negative energy balance in elite training athletes aspiring to lose weight, it has been estimated to raise daily protein intake to ~2–2.5 g/kg BW/day in an attempt to maintain muscle mass (for review, see Phillips, 2006). Furthermore, through a progressive resistance exercise program and ideal protein periodization, muscle mass can actually be 100% maintained while athletes still lose total BW during a 1-week period of a large (40%) negative energy balance (Mettler et al., 2010). In Mettler et al., subjects utilized a higher protein diet (~2.3 g/kg/day), with resistance exercise, to lose significant weight (~1.8 kg), of which ~78% was fat loss (~1.4 kg) and only 22% was muscle mass loss. In the control low protein diet, ~60% of the total weight loss came at the expense of muscle mass. Therefore, emerging data in both elite athletes and weight loss studies suggest that a combined approach of creating a caloric deficit, combined with increased protein intake and the implementation of a consistent exercise stimulus, appears to allow for total weight loss, while attenuating the loss of muscle mass (for review, see Phillips, 2006).

Perspective

An individual's phenotype (weight and body composition) is determined by interactions between genetic and environmental factors, with estimates of phenotypic heritability from epidemiological studies varying between 25% and 75% (Bouchard, 1994). Therefore, there will be a genetic limit to the extremes at which an individual can manipulate their phenotype and even more reason to create individualized body composition goals. Accordingly, this case study in a single Olympic-level female athlete is one step forward in a field that is lacking normative data, let alone best practice interventions. Nevertheless, for athletes in weight-dependent sports, realizing optimal body composition (e.g., power-to-weight ratio, lean muscle mass) is an important factor in obtaining the best possible periodized "peak." However, a periodized yearly and career approach will allow for this, while maximizing training adaptation and long-term athlete health.

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