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Anabolic hormone profiles in elite military men

Marcus K. Taylor [a,b,c,*], Shiloah A. Kviatkovsky [a], Lisa M. Hernández [a,b], Paul Sargent [d], Sabrina Segal [e], Douglas A. Granger [f,g,h]

[a] Biobehavioral Sciences Lab, Warfighter Performance Department, Naval Health Research Center, 140 Sylvester Road, San Diego, CA 92106-3521, United States
[b] Department of Exercise and Nutritional Sciences, San Diego State University, ENS Building, Room 351, 5500 Campanile Drive, San Diego, CA 92182, United States
[c] Institute for Interdisciplinary Salivary Bioscience Research, Arizona State University, 550 E. Orange Street, Tempe, AZ 85287, United States
[d] Naval Special Warfare Group ONE, 3632 Guadalcanal Road, Building 165, San Diego, CA 92155, United States
[e] Department of Psychology, Arizona State University, 550 E. Orange Street, Tempe, AZ 85287, United States
[f] Johns Hopkins School of Nursing and Bloomberg School of Public Health, 3400 North Charles Street, Baltimore, MD 21218, United States
[g] Institute for Interdisciplinary Salivary Bioscience, University of California – Irvine, Irvine, CA 92697, United States
[h] Salivary Bioscience Laboratory and Department of Psychology, University of Nebraska, 1400 R. Street, Lincoln, NE, United States

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ABSTRACT

We recently characterized the awakening responses and daily profiles of the catabolic stress hormone cortisol in elite military men. Anabolic hormones follow a similar daily pattern and may counteract the catabolic effects of cortisol. This companion report is the first to characterize daily profiles of anabolic hormones dehydroepiandrosterone (DHEA) and testosterone in this population. Overall, the men in this study displayed anabolic hormone profiles comparable to that of healthy, athletic populations. Consistent with the cortisol findings in our prior report, summary parameters of magnitude (hormone output) within the first hour after awakening displayed superior stability versus summary parameters of pattern for both DHEA (r range: 0.77–0.82) and testosterone (r range: 0.62–0.69). Summary parameters of evening function were stable for the two hormones (both $p < 0.001$), while the absolute decrease in testosterone across the day was a stable proxy of diurnal function ($p < 0.001$). Removal of noncompliant subjects did not appreciably affect concentration estimates for either hormone at any time point, nor did it alter the repeatability of any summary parameter. The first of its kind, this report enables accurate estimations of anabolic balance and resultant effects upon health and human performance in this highly resilient yet chronically stressed population.

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1. Introduction

We recently characterized the awakening responses [1] and daily patterns [2] of the catabolic stress hormone cortisol in elite military men. Anabolic hormones (e.g., dehydroepiandrosterone [DHEA] [3,4] and testosterone [5–7]) roughly follow the same daily pattern, loosely correlate to cortisol across the day [4], and appear to counteract cortisol's catabolic and neurodegenerative effects [8,9]. Testosterone, and to a lesser extent anabolic precursors such as DHEA, promote muscle growth, strength [10], and other desired adaptations to resistance training [9]. These hormones have individualized regulatory inputs, which may yield distinctions from cortisol in terms of magnitude and/or pattern of secretion across the day [4,11]. The concurrent study of catabolic and anabolic hormone function in healthy subjects is valuable because it builds a comparative knowledge base from which to elucidate aberrant neuroendocrine function in clinical conditions [11] and also informs subclinical "allostatic load" models of chronic stress [12]. These hormones are also routinely monitored to gauge training adaptations and optimize performance in competitive athletes [10,13].

Although some work has documented acute anabolic hormone responses in military settings [14,15], no published research has established daily, free-living profiles of military members. This creates a critical knowledge gap, given that military members are a unique population with an elevated risk of occupational stress [16], sleep disruption [17], trauma [18], and associated health consequences [19]. Some anabolic hormones are known to counteract such risks. For instance, military deployment erodes free testosterone concentrations [15], while both endogenous [14] and exogenous DHEA (a testosterone precursor) buffer stress profiles during military training [20], either through steroidogenic or independent neuroactive pathways. Likewise, sleep disruption—a pervasive military health challenge [17]—is linked to reduced

* Corresponding author at: Naval Health Research Center, 140 Sylvester Road, San Diego, CA 92106-3521, United States.
E-mail address: marcus.k.taylor2.civ@mail.mil (M.K. Taylor).

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testosterone concentrations [21] and compromised metabolic profiles, even in young men [22]. Furthermore, anabolic hormone concentrations are tied to posttraumatic stress disorder [23,24], and preclinical evidence points to DHEA sulfate supplementation as a potential rehabilitative tool for traumatic brain injury [25]. Clearly, precise characterization of anabolic hormone profiles in military members is a foundational step toward understanding and enhancing resilience in military members.

To date, some studies have characterized daily salivary DHEA patterns in diverse samples, including adolescents [3,11], athletes [26], college students [4], healthy adults [3,27,28], and older adults [29]. Fusing these results, salivary DHEA concentrations appear highest in the morning, may or may not maintain waking values for up to 45 min, and then decline roughly 50% throughout the day en route to an evening nadir. The evolving consensus is that salivary DHEA reveals no dynamic increase (i.e., stimulatory burst) upon awakening [4,11,26,27], which is in sharp contrast to the typical awakening morphology of cortisol [30].

Daily patterns of plasma and/or serum testosterone are relatively well-established in men of varied age groups [31], typically reflecting an observed peak at awakening followed by a continuous decline across the day, and then reaching a nadir in the evening. In recent years, characterizations of salivary testosterone have also accumulated in athletic men [5–7], healthy nonathletes [32], and clinical populations [33]. Shariat and colleagues, for example, documented daily salivary testosterone profiles in young, healthy male recreational weightlifters (mean age 18 years) assigned to a control (no exercise) condition, that showed peak values at 0600 (607.6 pmol/L; 175.1 pg/mL) and an evening nadir at 2200 (323.2 pmol/L; 93.1 pg/mL). Similar magnitudes and patterns have been shown in young healthy men with resistance training experience [5,7]. As with DHEA, testosterone does not appear to demonstrate a stimulatory burst upon awakening [5–7].

The stability of salivary DHEA across repeated sampling days has not been extensively researched, but the available data are promising. In a study of healthy adolescent females, Oskis et al. [11] showed that average morning salivary DHEA concentrations were very stable across 2 consecutive sampling days for both morning (i.e., average of waking and 30 min post waking; $r = 0.83$) and a single evening sample (12 h post waking; $r = 0.66$). Similarly, Hucklebridge et al. [4] reported excellent stability for salivary DHEA across consecutive days for averaged morning values as well as averaged values across the day (r range 0.87–0.92), which were superior to that of salivary cortisol (r range 0.57–0.76).

Some studies also quantified the repeatability of daily salivary testosterone measurements [7,32,34], and the findings are optimistic. Keevil et al. [32] reported that a single salivary testosterone sample taken before 1000 in healthy men and women (irrespective of menstrual phase) did not differ when repeated across either 4 consecutive weeks or 4 consecutive months. Kraemer and colleagues [7] evaluated testosterone concentrations at 17 data points across 2 consecutive sampling days in young athletic men, in both a rested condition and a condition that included an acute bout of resistance training. No intra-individual differences prevailed across the 2 days for either condition, with the exception of 0700 and 1700 in the rested condition.

Although important progress has been made linking poor sampling time compliance to distorted cortisol awakening responses [35], the effect of compliance on measurement of free-living DHEA or testosterone is extremely limited. One important exception is the work of Laudenslager and colleagues [27], which showed that the calculated slopes of diurnal decline in salivary DHEA of healthy men and women did not change appreciably upon exclusion of nonadherent subjects.

Despite this progress in diverse demographic sectors, remarkably little is known of the daily anabolic hormone profiles in military members. The present study was designed to (1) establish summary parameters of anabolic hormone (DHEA and testosterone) function in 58 elite military men, (2) evaluate the stability of summary parameters across 2 consecutive days of sampling, and (3) explore the effect of subject compliance with sampling times. As was shown with respect to cortisol in these men [1], we hypothesized that summary parameters of magnitude across the morning samples would reveal superior stability compared with summary parameters of pattern. In addition, we expected that summary parameters of daily hormone function (e.g., morning to evening slope) would demonstrate high stability. Furthermore, both summary parameters of magnitude and daily hormone function were expected to be robust to (i.e., show little distortion as a function of) noncompliance. Finally, unlike cortisol, no stimulatory burst of activity upon awakening was expected for either anabolic hormone.

2. Methods

2.1. Subjects

Subjects were male active-duty military members of the elite Navy Sea, Air, and Land (SEAL) community, assigned to Naval Special Warfare Group ONE located in San Diego, California. No subjects were in a deployed status; rather, all were in a routine training status at their home station. Those who expressed an interest in participating attended an in-person meeting to review the details of the study and provide written informed consent. This protocol was approved by the Naval Health Research Center Institutional Review Board.

2.2. Exclusion criteria and compliance instructions

Exclusion criteria imposed for this study included smoking (smokeless tobacco use was permitted with strict compliance criteria), current diagnosis of type 1 diabetes or type 2 diabetes with prescribed medication, and self-reported use of anabolic substances within the past 3 months. Compliance instructions were also provided. Specifically, subjects were asked to refrain from alcohol ingestion within 12 h of assessments; major meals, and smokeless tobacco product use within 1 h of assessments; ingestion of caffeine or dairy products within 30 min of assessments; and acidic or high-sugar foods/liquids or salivary stimulants (e.g., gum, lemon drops) within 10 min of each assessment.

2.3. Salivary sampling protocol

One salivary sample was taken five times per day for 2 days, for a total of 10 samples. The samples were self-collected by subjects in a free-living setting with oral swabs (Salimetrics, LLC, Carlsbad, CA). Each tube was labeled with the subject number, date, and expected time of sampling (e.g., WAKE + 30). Subjects were also instructed to write the exact time of sampling on the label. In order to minimize social desirability bias, it was explained that this information was needed solely for scientific purposes. Samples were collected during the workweek (Tuesday–Wednesday or Wednesday–Thursday) and all participants were encouraged to engage in their typical daily routines.

Concise, standardized instructions for self-administration of samples were provided to each subject. On each day, subjects were instructed to collect samples immediately upon waking, 30 min after waking, and 60 min after waking, as well as 1600 h (midafternoon) and 2100 h (evening). Each subject was asked to rinse his mouth with water approximately 10 min prior to sample collection, to place all used oral swabs in a small cooler pre-packed with