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Effects of high-intense resistance training on salivary cortisol in trained individuals: a systematic review
Efectos del entrenamiento de resistencia de alta intensidad sobre el cortisol salival en individuos entrenados: una revisión sistemática

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Abstract. This study aimed to evaluate the effects of high-intensity training (HIT) on salivary cortisol levels in physically trained individuals. This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations. The search for scientific articles was carried out on the Scopus and MEDLINE (via PubMed) databases with the terms *resistance training*, *saliva*, *cortisol*, and their synonyms. We included interventions with high-intense resistance training that analyzed the salivary cortisol levels in physically trained men and women. From the 399 articles found, eight studies met the inclusion criteria. A population of 135 physically trained men and 12 women is with an average age of 23.26 ± 3.10 years, body mass of 85.53 ± 12.68 kg, and height of 1.80 ± 0.04 m. The intervention period ranged from 3 to 15 weeks with the use of 1 to 5 sets of 5 to 10 repetitions. Most protocols have been shown to provide significant stimuli to increase the level of cortisol acutely ($p<0.05$). The practice of HIT seems to be an effective intervention to stimulate the increase in acute and chronic salivary cortisol levels and thus induce possible changes in physiological and hormonal levels. Moreover, cortisol seems to represent physical activity in some populations and may be useful in monitoring physiology in large-scale observational physical activity surveys. However, more research is needed to elucidate the effects of HIT on cortisol and adaptive results.
Keywords: Resistance training, Saliva, Cortisol.

Resumen. Este estudio tuvo como objetivo evaluar los efectos del entrenamiento de alta intensidad sobre los niveles de cortisol salival en individuos entrenados físicamente. Esta revisión sistemática siguió las recomendaciones de PRISMA. La búsqueda de artículos científicos se realizó en las bases Scopus y MEDLINE (vía PubMed) con los términos entrenamiento de resistencia, saliva, cortisol y sus sinónimos. Se incluyeron intervenciones con entrenamiento de resistencia de alta intensidad que analizaron los niveles de cortisol salival en hombres y mujeres entrenados físicamente. De los 399 artículos encontrados, ocho estudios cumplieron los criterios de inclusión. Una población de 135 hombres entrenados físicamente y 12 mujeres tiene una edad de 23,26±3,10 años, masa corporal de 85,53±12,68 kg y altura de 1,80±0,04 m. El período de intervención varió de 3 a 15 semanas con el uso de 1 a 5 series de 5 a 10 repeticiones. Se ha demostrado que la mayoría de los protocolos proporcionan estímulos significativos para aumentar el nivel de cortisol de forma aguda ($p<0,05$). La práctica de entrenamiento de alta intensidad parece ser una intervención eficaz para estimular el aumento de los niveles de cortisol salival agudo y crónico y así inducir posibles cambios en los niveles fisiológicos y hormonales. Además, el cortisol parece representar la actividad física en algunas poblaciones y puede ser útil para monitorear la fisiología en encuestas observacionales de actividad física a gran escala. Sin embargo, se necesita más investigación para dilucidar los efectos de entrenamiento de alta intensidad sobre el cortisol y los resultados adaptativos.
Palabras clave: Entrenamiento de resistencia, Saliva, Cortisol.

Introduction

Resistance exercises, especially those performed at high intensity, cause significant endocrine changes, both acute and chronic in an effective stimulus for the hypothalamic-pituitary-adrenal axis, resulting in a significant increase in circulating cortisol levels (Becker et al., 2020; Wilk et al., 2018a).

Cortisol is a glucocorticoid secreted by the adrenal cortex of the adrenal glands and exerts many beneficial effects in humans, increasing the availability of metabolic substrates, maintaining normal vascular integrity, and protecting the body from an exaggerated response of the immune system to exercise-induced muscle damage (Becker et al., 2020; Vale et al., 2012). Cortisol plays important roles during and after exercise, including participating in gluconeogenesis and accelerating the mobilization and use of fats for energy production

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(Becker et al., 2020; Vale et al., 2012).

Cortisol levels increase at a relatively proportional rate in response to high-intensity training (HIT). Depending on the characteristics of stimuli, these responses can be classified as acute and chronic (Bonato et al., 2017). For these reasons, the HIT can be used to promote an increase in salivary cortisol levels and determine acute physiological stress (Ciolac & Silva, 2016).

These changes can induce, in athletes and physically trained individuals, an adaptive response to mechanical stress caused by weight resistance, which can promote increases in muscle mass, muscle strength and hypertrophy due to HIT. During training sessions, many catabolic actions occur (ACSM, 2017; Arazi et al., 2019; Bonato et al., 2017). These catabolic actions can generate tissue damage necessary to muscle fibers so that the cell regeneration process occurs in greater proportions during the rest period, after the training sessions. This can stimulate the gains of hypertrophy and muscle strength (Arazi et al., 2019; Crewther et al., 2011).

Therefore, HIT can promote an acute increase in cortisol secretion, which plays a role in stimulating glycogenesis, accelerating and mobilizing free fatty acids, and initiating glucose maintenance (Anderson et al., 2016). There may be an increase in metabolic response, which can be evidenced by decreased pH and increased lactate concentrations (Geisler et al., 2019). This can occur due to the high volume of training and intensity and short intervals of muscle recovery between the sets of exercises (Church et al., 2016). Thus, there are greater stimuli in type II muscle fibers, which are responsible for higher production of strength, power, and speed (Raya-González et al., 2018).

Cortisol acts as a physiological antagonist of insulin because it promotes the breakdown of carbohydrate, lipid, and protein molecules. Generally, salivary cortisol has been used to study the chronic and acute effects of training in place of blood test analysis, which is more invasive and causes discomfort in trained individuals or athletes (Wunsch et al., 2019).

The salivary cortisol collection is a method that involves a simple procedure that does not produce enough changes to significantly interfere with the results. Because it is a non-invasive technique, the collection is not stressful, unlike venous puncture, which many consider painful (Vale et al., 2012). This collection procedure allows an adequate analysis and prediction of cortisol levels in response to the intervention (Pineda-Espejel et al., 2020).

Thus, this systematic review aimed to evaluate the effects of HIT on salivary cortisol levels in physically trained individuals.

Methods

This systematic literature review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009).

Eligibility criteria

Table 1 shows the PICOS strategy used to delimitate the inclusion criteria. We excluded review studies, studies with animals or diseases, studies with other populations, and studies that used aerobic training as intervention.

Table 1.
PICOS strategy

Initials	Description	Analysis
P	Participants	Physically trained men and women
I	Intervention	High-intensity resistance training
C	Comparison	Pre- *vs.* post-intervention
O	Outcomes	Effects of HIT on salivary cortisol levels
S	Study design	Experimental studies

HIT: High-intensity training.

Search strategy

A systematic search was performed without time or language filters in the electronic databases Scopus and MedLine (via PubMed), with last updated in April 2020. We used the descriptors «resistance training», «saliva», and «cortisol» and their synonyms, available at Health Sciences Descriptors (DeCS) and Medical Subject Headings (MeSH). The search was performed with the Boolean operators [OR] (between synonyms) and [AND] (between descriptors). We checked the references of the selected studies and other sources to maximize the search.

After the references were extracted using the search terms, they were exported to a shared library on Mendeley Desktop. Two authors completed the research, the removal of duplicates, the analysis of titles and abstracts, and the screening of the complete articles. Any differences in the analysis were sent to a third author. Then, we read the full version of the articles assessed for eligibility and those that did not meet the inclusion/exclusion criteria were removed.

Bias analysis

The Risk of Bias In Non-randomized Studies – of Interventions (ROBINS-I) tool was used to assess the risk of bias in the studies included in this systematic review (Sterne et al., 2016). Two independent and experienced evaluators analyzed the risk of bias in the included studies. Disagreeing assessments were solved by a third researcher. The studies were classified as «selection bias», «performance bias», «detection bias», «follow-up bias», «report bias», «lack of data bias», and «bias in result selection reported», and were evaluated in the domains «yes», «Probably yes», «Probably not», and «No». Responses of «Yes» and «No» are intended to have similar implications to responses of «Probably yes» and «Probably no», respectively. Each «Yes» or «Probably yes» corresponds to 1 point. The scores of the sum of the seven domains are: one or two points = severe risk of bias, three or four points = moderate risk of bias, and five to seven = low risk of bias.

Results

In total, 399 studies were found following the proposed research methodology. After using the selection criteria, eight articles were included in this review (Figure 1).

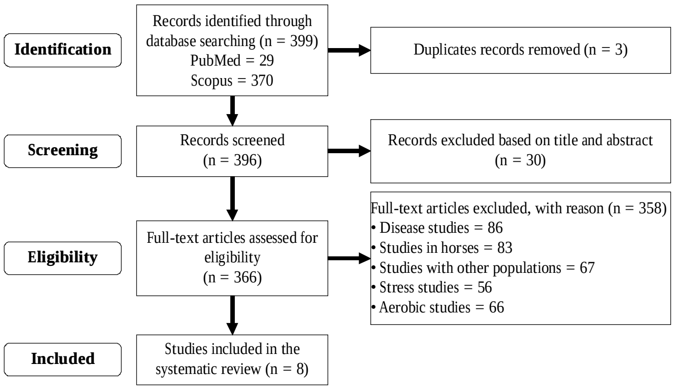

Figure 1. Flow chart of the selected articles

Table 2 presents the characteristics of the eight included studies. The total number of participants was 147 physically trained individuals (135 men and 12 women), with an average age of 23.26 ± 3.10 years, body mass of 85.53 ± 12.68 kg, and height of 1.80 ± 0.04 m.

Table 3.
Methods and outcomes of the studies included in this review

Studies	Test	Load, in kg (Mean ± SD)	Exercise	Intervention period	Cortisol result (Mean ± SD)	*p*-value
Anderson et al. (2016)	1RM	145.45 ± 26.87	Bench press Squat clean	12 weeks	↑ 5.33 ± 4.94 ↑ 2.57 ± 2.46	p<0.05
Bartolomei et al. (2014)	1RM	118.45 ± 25.69	BS+BP+DPB+D+SC+TPD+PBR+LM+PU+DR+SBC+PC+LP+LE/LC+MP+UR+LL+IBP+LR+PLL+IDC+PC	15 weeks	↑ BP + 19.0% ↑WWP + 21.3%	p<0.05 p<0.05
Cintineo et al. (2018)	10RM	NR	LP+LE+RD+ILC+AS+SCL	2 days	↑HIT = 0.3 ± 0.1 ↑3S = 0.47 ± 0.21	p<0.01 p<0.05
Gaviglio et al. (2015)	1RM	76.67 ± 37.86	HR+HBP+S+CU+PR	4 weeks	↓ 0.19 ± 0.17 ↓ 0.20 ± 0.15	p<0.01 p<0.01
Geisler et al. (2019)	1RM	109.75±15.75	Back-squat HBP	3 days	↑ 11 mmol/L ↑0.6 mmol/L	p<0.05
Genner and Weston (2014)	1RM	105.96±20.98	BS + CP DB + OR+ RD	1 week	↑ 148 ± 15.6 ↑ 102 ± 18.4 ↑ 19 ± 44	NR
Sinclair et al. (2013)	Isokinetic	130.18±41.55	Leg flexion Leg extension	3 weeks	↑ M = η2 = 0.68 ↓W = η2 = 0.25	p<0.01 p<0.01
Weakley et al. (2017)	3RM	471.6 ± 191.02	HBP+RD+DSP+BOR+UR	4 weeks	↓TRAD = 0.10 ± 0.07 ↓ SS = 0.14 ± 0.17 ↔ HIT = 0.15 ± 0.13	NR

SD: Standard deviation, RM: repetition maximum, WWP: Weekly wavy periodization, BP: bench press, DBP: Dumbell bench press, D: Dips, SC: Skull crushers, TPD: Triceps pull down, PBR: Prone barbell row, LM: Lat machine, PU: Pull up, DR: Dumbell row, SBC: Standing barbell curl, PC: Preacher curl, BS: Back squat, LP: Leg press, LE: Leg extension, LC: Leg curl, MP: Military press, UP: Upright row, LL: Lateral lift, IBP: Inclined bench press, LR: Low row, PLL: Prone lateral lifts, IDC: Inclined dumbell curl, PC: Preacher curl, BS: Back squat, CP: Chest press, BD: Bench press, DSP: Dumbbell shoulder press, UR: Upright row, BOR: Bent over row, CU: Chin-ups, PR: Prone row, HR: High pull, RD: Romanian deadlift, ILC: Inclined leg curl, AS: Adductor seated, SCL: Seated calf lift, LFE: Leg flexion and extension, TRAD: Traditional, SS: Superset, HIT: High-intensity training, NR: Not reported, M: men; W: women, ↑ increase, ↓decrease, ↔maintenance.

Table 3 shows the methods and the main outcomes of the studies included in this review. Of the eight studies, seven used the maximum repetition test (RM) (Anderson et al., 2016; Bartolomei et al., 2014; Gaviglio et al., 2015; Geisler et al., 2019; Genner & Weston, 2014; Weakley et al., 2017) and one used the isokinetic device (Sinclair et al., 2013). Two studies showed a decrease in cortisol levels (Genner & Weston, 2014; Weakley et al., 2017). Two other studies (Sinclair et al., 2013; Anderson et al., 2016) showed an increase and decrease. One study (Sinclair et al., 2013) showed an increase in cortisol levels in men and a decrease in women. One study (Anderson et al., 2016) showed an acute increase in salivary cortisol levels after the first intervention and a chronic increase after 12 weeks. Three experiments (Bartolomei et al., 2014; Geisler et al., 2019; Genner & Weston, 2014) showed sharp increases in cortisol levels after the intervention.

Table 4 shows the studies' risk of bias through the ROBINS-I tool. According to this tool, one study

Table 2.
Study characteristics

Authors/year	Country	Sample	Population characteristics		
			Age (years)	Height (m)	Body mass (kg)
Anderson et al. (2016)	USA	20 M	19.1 ± 1.1	1.85 ± 6.7	102.0 ± 22.2
Bartolomei et al. (2014)	Italy	18 M	26.0 ± 7.8	1.77 ± 0.05	78.7 ± 0.28
Cintineo et al. (2018)	USA	19 M	21.11 ± 2.5	174.33 ± 6.83	76.72 ± 10.24
Gaviglio et al. (2015)	England	27 M	28.3 ± 4.0	1.87 ± 0.08	107.6 ±18.9
Geisler et al. (2019)	Germany	13 M	23.4 ± 1.3	1.82 ± 5	81.8 ± 6.4
Genner and Weston (2014)	USA	12 M	25.4 ± 6.9	1.80 ± 7	77 ± 10
Sinclair et al. (2013)	England	12 M and 12 W	22 ± 0.71	1.78 ± 8.4	73.15 ± 6.9
Weakley et al. (2017)	England	14 M	20.8 ±1.2	1.81 ± 0.06	87.3 ± 6.2

USA: United States of America; M: men; W: women.

Table 4.
Analysis of risk of bias using the ROBINS-I tool

Studies	1	2	3	4	5	6	7	Total
Anderson et al. (2016)	P. No	No	No	No	Yes	No	No	1
Bartolomei et al. (2014)	P.Yes	P. No	P.Yes	No	No	P.Yes	No	3
Cintineo et al. (2018)	P.Yes	P.Yes	No	Yes	Yes	P.Yes	No	5
Gaviglio et al. (2015)	P.Yes	P.Yes	Yes	Yes	Yes	Yes	No	6
Geisler et al. (2019)	P.Yes	P.Yes	Yes	No	No	P.Yes	No	4
Genner and Weston (2014)	P.Yes	Yes	P. No	No	No	P.Yes	No	3
Sinclair et al. (2013)	P.Yes	P.Yes	P.Yes	No	No	P. No	No	3
Weakley et al. (2017)	P.Yes	Yes	P.Yes	Yes	Yes	P.Yes	No	6

P: Probably, 1: Bias due to confounding, 2: Bias in selection of participants into the study, 3: Bias in classification of interventions, 4: Bias due to deviations from intended interventions, 5: Bias due to missing data, 6: Bias in measurement of outcomes, 7: Bias in the selection of the reported result.

(Anderson et al., 2016) was considered with a serious risk of bias, four studies (Bartolomei et al., 2014; Geisler et al., 2019; Genner & Weston, 2014; Sinclair et al., 2013) showed a moderate risk of bias, and three studies (Cintineo et al., 2018; Gaviglio et al., 2015; Weakley et al., 2017) presented a low risk of bias.

Discussion

This review aimed to investigate the effects of high-intense resistance training on salivary cortisol levels in physically trained individuals. Of the eight studies, seven used HIT in interventions in traditional bodybuilding machines and or free weights (Anderson et al., 2016; Bartolomei et al. 2014; Cintineo et al., 2018; Gaviglio et al., 2015; Geisler et al., 2019; Genner & Weston, 2014; Weakley et al., 2017) and one study used the isokinetic device (Sinclair et al., 2013).

The analysis of the included studies showed that the practice of HIT, with protocols of exercises performed in two or fifteen days, caused a significant response to cortisol during exercise and recovery. Additionally, the eight studies demonstrated that proper manipulation of all protocols and variables is crucial to obtain these responses after 2 to 15 weeks of HIT due to the o high volume of training.

The endocrine system is particularly sensitive to resistance exercises and changes in anabolic and catabolic hormones and has been associated with the post-exercise reconstruction process of damaged muscle cells and, therefore, the magnitude and the taxed post-exercise adaptation (Wilk et al., 2018a).

It is important to note that five studies (Anderson et al., 2016; Bartolomei et al., 2014; Cintineo et al., 2018; Geisler et al., 2019; Genner & Weston, 2014) showed that, after the HIT intervention, there was a chronic increase in muscle strength and an acute increase in cortisol levels, and two studies (Gaviglio et al., 2015; Weakley et al., 2017) showed a chronic decrease in cortisol levels after the intervention. In these two studies, it seems that the ideal volume and intensity of the training loads can stimulate catabolic hormones more effectively and this was not determined. This may be due to several factors such as the speed of movement for an exercise, age, gender, training experience, type of muscle contractions used that complicate this problem. Additional factors include equipment type, diet, supplementation, and how these factors interact with a genetic endowment (Wilk et al., 2018b).

Another study (Sinclair et al., 2013) showed an acute increase in cortisol levels in men and a decrease in women post-intervention. This study (Sinclair et al., 2013) performed the intervention in the morning, afternoon, and evening, to verify the influence of circadian rhythms on metabolic cortisol response acutely in 12 men and 12 women aged between 21 and 22 years. Saliva samples were collected at three different times: in the morning (collection 1), in the afternoon (collection 2), and in the evening (collection 3), in three sessions separated for seven days. The authors reported that the investigation showed circadian variation in the acute increase in cortisol level after the intervention in the afternoon and evening in men and the lowest level in women in the morning.

These results are in agreement with Parastesh et al. (2019), who investigated the effect of salivary cortisol in the morning, in 15 young athletes after an intense exercise session. According to the results found, there was no increase in salivary cortisol level in young athletes after the intervention. This showed that the intervention period in the women studied caused low stress to stimulate an increase in cortisol level. As a final product, cortisol acts negatively, suppressing activity in the hippocampus and pituitary gland.

The findings of Sinclair et al. (2013) confirm the results of Teo et al. (2011) when investigating the effect of circadian rhythm on cortisol in 20 men with 23 years, in four sessions of resistance exercise. The hormonal response induced by strength tests showed a significant increase in acute cortisol levels in the afternoon and evening. On the other hand, Radaelli et al. (2015), Cintineo et al. (2018), and Berelleza et al. (2020) concluded that HIT may increase short-term adaptive responses in the short term of hypertrophic and strength due to increased cortisol concentrations and that this occurs only when appropriate intensity thresholds are reached in the hypothalamus-pituitary-adrenal (HPA).

Weakley et al. (2017) examined the influence of three training methods on hormonal responses. The individuals were randomly divided into three groups, submitted to simple methods of series, superset, and tri-set. The authors describe that the group submitted to the superset method showed a significant increase in cortisol levels in response to acute and chronic stress compared to the groups submitted to tri-set methods and simple series. The results obtained in this study suggest that the super defined method promoted a more favorable environment for anabolism after four weeks of intervention.

Cintineo et al. (2018) evaluated acute hormonal responses in a single high-intensity eccentric training and a traditional 3-sets protocol. Participants were randomly divided into two training groups of three sets (3TS; n = 9) and another HIT group (HIT; n = 10) using a computer-generated resource list of numbers. The reports in this study showed that the 3TS and HIT groups obtained a significant increase in cortisol levels after the intervention. Nevertheless, the 3TS group showed a more robust level of cortisol. This may have run due to longer time on muscle group tension, generating the potentially unique effects of acute biochemical data volume, and physiological and hormonal responses.

Cintineo et al. (2018) observed that cortisol response increased during exercise and post-exercise and remained elevated for 30 minutes after exercise in the 3ST group, while the HIT group showed no change in cortisol in relation to baseline at any time. This is due to the training volume was higher in the 3ST group than in the HIT group. The results of this study also indicate that the amount of induced metabolic stress was higher in the 3ST protocol compared to the HIT protocol.

This is consistent with the findings of Klemp et al. (2016), showing that one set and 3 sets resistance training protocol causes a more robust response to cortisol during exercise and recovery compared to a single set protocol. On the other hand, Wilk et al. (2018a) found that acute cortisol can regulate long-term changes in muscle strength and hypertrophy, especially due to HIT volume.

These changes in cortisol concentrations can moderate or support the performance capacity of the neuromuscular system through several short-term mechanisms, including gluconeogenesis stimulation and glycogen synthesis in the liver and its ability to inhibit protein synthesis and stimulate protein degradation in peripheral tissues and muscle properties (Adebero et al., 2019).

Mangine et al. (2016) reported that the HIT method promotes effect and adaptation in the human neuromuscular system in the manipulation of training variables, number of sets, intensity, recovery intervals, muscle contraction speed, and exercise order. Thus, it can induce possible acute changes in physiological and hormonal levels, offering short-term neuromuscular adaptation for energy performance and, in the long term, muscle strength and hypertrophy (Crewther & Christian, 2010).

Similarly, two experimental studies (Geisler et al., 2019; Genner & Weston, 2014) used HIT exclusively as an intervention and found significant acute and chronic increases in salivary cortisol levels concentrations ($p<0.05$). To Crewther and Christian (2010), this hormonal response after HIT intervention is due to an adaptation to training, partly due to individual variation in response to strength exercise, hypertrophy, and long-term, and, in the short term, to the neuromuscular system in trained individuals.

Hence, Wilk et al. (2018a) state that changes in endogenous hormonal cortisol may have different responses in training for highly trained individuals in the short term and the lack of any change may reflect as an adaptation to training. Thus, the different responses of cortisol may play important roles in mediating the adaptation of training with one or more mechanisms involved, such as muscle and motor unit development, emotional and behavioral changes, and mobilization of metabolic resources (Crewther et al., 2016).

Thus, highly trained individuals may also have ideal neuromuscular profiles to promote short-term effects on cortisol, as they have a larger type II transverse muscle area and a higher percentage of type II fibers compared to trained individuals (Crewther et al., 2011; Geisler et al., 2019). However, this relation may be better detected on an individual level among the populations of trained individuals, but with two important observations. First, these relationships may depend on the subject's strength levels or training experience. Second, its detection (or lack thereof) may also reflect the analytical approach and whether individual differences or changes are compared (Crewther et al., 2012). Addressing these issues within the same structure would provide a greater understanding of the role of cortisol in mediating adaptations in athletic populations and trained individuals (Crewther et al., 2016).

This review has limitations that should be highlighted. The analyzed studies did not perform long periods of saliva collection after interventions to obtain better insights on the process of change in the hormonal level and the salivary cortisol levels after physical stress. Another factor is that the results of these studies are only based on samples of trained individuals. In addition, it should also be noted the lack of information on the methodologies on the accuracy and reproducibility used in the studies. Furthermore, restrictions in the search strategy may have caused a loss of information available in the scientific literature. Thus, the findings of this review should be analyzed with caution and critical reading of the outcomes must be carried out.

Conclusion

HIT appears to be an effective intervention to stimulate increased acute and chronic salivary cortisol levels and thus induce possible changes in physiological and hormonal levels. However, from the limited evidence presented in this review, cortisol appears to be a viable biomarker for monitoring HIT responses and health-related outcomes. In particular, it appears that cortisol may be influenced by an intensity limit since changes in cortisol seem to occur in interventions of a higher training volume in those who presumably have a reduced training tolerance. Moreover, cortisol seems to represent physical activity in some populations and may be useful in monitoring physiology in observational large-scale physical activity research. However, more research is needed to elucidate the effects of cortisol on HIT performance and adaptive results.

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