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original research

An 8-Year Longitudinal Study of Overreaching in 114 Elite Female Chinese Wrestlers

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Context: Successful training involves structured overload but must avoid the combination of excessive overload and inadequate recovery.

Objective: The aim of this study was to determine the incidence of functional overreaching (FOR), nonfunctional overreaching (NFOR), and overtraining syndrome in elite female wrestlers during their normal training and competition schedules and to explore the utility of blood markers for the early detection of overreaching. Classification of FOR, NFOR, and overtraining syndrome was based on the European Congress of Sports Medicine position statement.

Design: Case series.

Setting: China Institute of Sport Science.

Patients or Other Participants: Over an 8-year period, 114 wrestlers from the women's Asian wrestling team were monitored to help identify if and when they experienced FOR, NFOR, or overtraining syndrome.

Main Outcome Measure(s): Creatine kinase, hemoglobin, testosterone, and cortisol were measured throughout the period to identify whether wrestlers were outside the reference intervals (constructed from normal recovery data) during periods of overreaching and not overreaching.

Results: Among the 114 athletes, there were 13 (3.6%) instances of FOR, 23 (6.4%) instances of NFOR, and 2 (0.6%) instances of overtraining syndrome. The diagnostic sensitivity for FOR was 38%, 15%, 45%, and 18% for creatine kinase, hemoglobin, testosterone, and cortisol, respectively. The diagnostic sensitivity for NFOR was 29%, 33%, 26%, and 35% for creatine kinase, hemoglobin, testosterone, and cortisol, respectively. Specificity was 79%, 88%, 90%, and 82% for creatine kinase, hemoglobin, testosterone, and cortisol, respectively. Post hoc analysis showed no mean differences in creatine kinase ($F = 0.5$, $P = .47$), hemoglobin ($F = 3.8$, $P = .052$), testosterone ($F = 0.2$, $P = .62$), or cortisol ($F = 0.04$, $P = .85$) between monitoring periods when wrestlers were and were not diagnosed with FOR and NFOR.

Conclusions: Coaches and sports scientists should not use single blood variables as markers of overreaching in elite female wrestlers.

Key Words: blood markers, fatigue, overtraining, underperformance

Key Points

- The incidence of overtraining was high (69%) in world-class female wrestlers.
- The blood variables creatine kinase, hemoglobin, testosterone, and cortisol were not useful markers for the early detection of overreaching.

An imbalance between training stress and recovery is known as *overtraining* and can result in functional overreaching (FOR), nonfunctional overreaching (NFOR), and overtraining syndrome (OTS).[1,2] Functional overreaching is considered a desirable component of training for elite athletes because of the relatively short recovery time (within 2 weeks) and the associated supercompensatory effect that elicits improved athletic performance.[3] In contrast, recovery from NFOR may take several weeks to months and hence has a negative effect on athletes' training programs. Furthermore, recovery from OTS may take months to years and is characterized by a prolonged decrease in performance, persistent fatigue, and mood disturbances, all of which seriously compromise the competitive athlete.[2,4] The incidence of NFOR and OTS has been estimated to be in the range of 5% to 60% of all athletes during their sports career.[5–9] Therefore, this problem continually needs to be addressed by coaches and scientific support staff. The process of intensified training leading to FOR, NFOR, and OTS is often viewed as a continuum, and the thresholds between these 3 states are extremely narrow. Thus, athletes and coaches need accurate and reliable diagnostic tools to identify overtraining so that timely recovery interventions can be implemented to avoid the negative consequences associated with NFOR and OTS.

In the last few decades, considerable research has indicated that FOR, NFOR, and OTS may be identified using diagnostic blood markers,[10–18] physiologic perturbations,[11,16,19,20] and negative changes in the athlete's psychological state.[14,16,18,21–23] Most authors who have investigated the early signs of overtraining have relied on deliberately inducing a state of overreaching by exposing athletes to short periods of intensified training.[10,13,20–23]

Such studies, however, rarely reflect the normal training and competition schedules of elite athletes, are difficult to conduct, and raise a variety of ethical concerns. Cross-sectional studies focusing on diagnostic markers of NFOR and OTS generally include athletes from sports medicine clinics in which athletes experiencing OTS are highly represented.[17,18] Unfortunately, such investigations do not reveal any information about the incidence of FOR, NFOR, and OTS during the athletes' normal training and competition schedules. These studies also do not provide information on the development of FOR and NFOR because they focus on the end stages of the overtraining continuum. Few authors of longitudinal studies have attempted to document the incidence of NFOR and identify early markers of FOR and NFOR within a naturalistic sports setting, and, to the best of our knowledge, no studies have investigated overreaching in elite wrestlers.

The main aim of our study was to report the incidence of FOR, NFOR, and OTS in elite female wrestlers, using a longitudinal 8-year observation of the Chinese women's wrestling team during their normal training and competition schedules. A second aim was to explore the utility of blood markers for the early detection of overreaching.

METHODS

Participants

A total of 114 women from the national Chinese wrestling team were included in the study. The wrestlers were preparing for national and international competitions (including the 2006, 2007, 2008, 2010, and 2011 world championships) from November 2003 to May 2012. Other competitions included the World Cup, the Asian Championship, and various qualification tournaments. All the wrestlers included in the study were medal winners in various national and international wrestling tournaments. The Chinese women's wrestling team had won gold medals in 5 consecutive World Cups (2007, 2008, 2009, 2010, and 2011), and 13 of the 114 wrestlers included in the study had ranked in the top 3 in world championships. The minimum time for observing each wrestler during the 8-year monitoring period of the study was 1 year, and each of the 13 wrestlers ranked in the top 3 in the world championships were monitored for more than 4 years. Demographic characteristics are shown by Olympic weight class[24] in Table 1. The study was approved by the Institutional Ethics Committee of the China Institute of Sport Science, Beijing, and all participants provided written informed consent. Because no participants were <18 years old, parental consent was not required.

Procedures

Training Overview. The wrestlers trained year round during the monitoring period, with training loads that the coaches varied on a weekly basis. Training was divided into high-, medium-, and light-load weeks and an adjusted training-load week that was prescribed according to individual wrestlers' training requirements. Individualized training was achievable because of the relatively low ratio of wrestlers to coaches. In the high-load week, the training arrangement was as follows: high-load training in the morning (9 AM–noon) and afternoon (3–6 PM) on Monday, Tuesday, Thursday, and Friday and low-load training in the morning on Wednesday and Saturday. In the medium-load week, the intensity and volume were both reduced to half, or only 1 factor was reduced to half. The light-load week comprised only 3 half-days of low-load training, and in the adjusted week, athletes undertook recreational activities consisting of basketball, football, and other team or individual activities at low intensity.

Table 1. Wrestlers' Characteristics (N = 114)

Weight Class, kg	Wrestlers, No.	Mean ± SD		
		Age, y	Height, cm	Body Mass, kg
48	31	22 ± 3	158.9 ± 3.5	52.7 ± 1.7
55	30	23 ± 2	163.5 ± 2.8	60.4 ± 2.2
63	32	23 ± 3	168.1 ± 2.2	67.1 ± 1.8
72	21	23 ± 2	173.6 ± 2.5	74.0 ± 2.3
Total	114	23 ± 2	165.4 ± 5.9	62.7 ± 7.9

Classification of FOR, NFOR, and OTS. Classification of FOR, NFOR, and OTS was based on the European Congress of Sports Medicine Position Statement[2,3]:

- Functional overreaching: The wrestler experienced decreased training performance, which was followed by full recovery and enhanced competition performance within 2 weeks of engaging in an appropriate recovery regimen.
- Nonfunctional overreaching: Episodes of decreased competition performance lasted 2 to 6 weeks.
- Overtraining syndrome: Episodes of decreased competition performance lasted more than 6 weeks.[4]

Training Performance Assessments. Female freestyle wrestling is a sport requiring strength, power, agility, and endurance. It is difficult to select 1 or 2 specific capacity indices that are related to competition performance, and it is also difficult to design tests that diagnose specific performances under laboratory conditions. Additionally, it is impractical to measure the specific capacity index each week, especially in the precompetition training period. In this study, experienced coaches assessed performance decrement based on the athlete's inability to maintain the training load and a decrease in the combative scoring point, which was evaluated by the scoring rate during each competitive bout. Full recovery was confirmed when the athlete could maintain high-intensity training and raise the scoring capability. If the 2 indicators could not be achieved simultaneously, full recovery was not recognized even though the biochemical factors had recovered to within the normal range.

Decreased competition performance was assessed only by experienced coaches without any input from the individual wrestler and was based on the wrestler's inability to maintain the scheduled training load and decreased combative scoring point. The combative scoring point system uses a 6-point scale: 0 = *the athlete was "off her game" and performance was significantly decreased*; 1 = *performance was better than 0 but still lowered*; 2 = *performance was slightly below normal*; 3 = *no improvement from the original level*; 4 = *performance was slightly enhanced*; and 5 = *performance had improved considerably and the athlete was performing at a high level*. Coaches were not aware of blood analysis results at the time the combative scoring point was being assessed.

Measurement of Blood Variables. To establish whether any blood markers could be used as early warning signs of FOR, NFOR, or OTS, blood samples were taken from an antecubital vein on a Monday morning between 7 and 8 AM, after an overnight fast and at least 24 hours after any physical training. Athletes were instructed to remain fully hydrated within the 24 hours before scheduled blood sampling. Blood samples were taken either each week or every 4 weeks during the monitoring period, depending on the national and international ranking of the wrestler. Restricting some wrestlers to blood analyses every 4 weeks was necessitated by logistics such as time and cost. The blood samples were analyzed for the concentrations of creatine kinase, hemoglobin, testosterone, and cortisol. Serum creatine kinase activity was determined using the enzyme-coupled assay and activation of *N*-acetyl-L-cysteine with an automatic biochemical analyzer (model 7020; Hitachi Ltd, Tokyo, Japan). Hemoglobin was measured using a Coulter Ac·T diff2 Hematology Analyzer (Beckman Coulter, Brea, CA). Serum testosterone and serum cortisol levels were analyzed using an Access 2 Immunoassay System (Beckman Coulter).

Statistical Analyses

Statistical analyses were completed using IBM SPSS software (version 19; SPSS Inc, Chicago, IL) unless otherwise stated. The central tendency and dispersion of normally distributed data are reported as the mean (±SD) and otherwise as the median (interquartile range). To establish the diagnostic sensitivity and specificity of hemoglobin, creatine kinase, testosterone, and cortisol as blood markers for FOR and NFOR, we calculated reference intervals by adding and subtracting 1.96 SD to and from the mean response of the normal recovery data. The creatine kinase data exhibited considerable positive skewness, and therefore robust reference intervals were obtained after Box-Cox transformation using an Excel (Microsoft Inc, Redmond, WA) macro.[25] Diagnostic sensitivity of the blood markers was calculated as $(a/[a+b]) \cdot 100$, where a is the number of true-positive outcomes and b is the number of false-negative outcomes.[26] Specificity was calculated as $(c/[c + d]) \cdot 100$, where c is the number of true-negative outcomes and d is the number of false-positive outcomes. Exploratory data analysis of the variance in creatine kinase, hemoglobin, testosterone, and cortisol values explained by between-subjects differences and a post hoc analysis of the mean difference in blood variables between athletes who were and were not diagnosed with overreaching and OTS were performed using linear mixed modeling. Statistical assumptions regarding the distribution of the residuals were checked using standard graphical methods.[27] When residuals were not normally distributed, we rectified this by using the natural log transformation of the observed data. Statistical significance was accepted as $P < .05$.

RESULTS

Incidence of FOR, NFOR, and OTS

The frequencies of FOR, NFOR, and OTS for the 114 wrestlers during the 8-year monitoring period are shown in Table 2. There were 13 instances of FOR, 23 instances of NFOR, and 2 instances of OTS. Categorization of FOR, NFOR, and OTS was mutually exclusive for a given wrestler in a given training period for a competition; for example, a wrestler recorded as experiencing NFOR within a competition training period was not also recorded as experiencing FOR. During the 8-year monitoring period, 1 wrestler experienced FOR on 3 occasions, 2 wrestlers experienced FOR twice, and 6 wrestlers experienced it once. Two wrestlers experienced NFOR on 3 occasions, 3 wrestlers experienced NFOR twice, and 11 wrestlers experienced it once. Nine of the 13 athletes (69%) who had ranked in the top 3 at the world championships experienced NFOR at least once. The 2 instances of OTS occurred in different wrestlers. Taking into account the number of wrestlers on the team and the number of incidences of overreaching and OTS during a given monitoring period, prevalences were 3.6%, 6.4%, and 0.6% for FOR, NFOR, and OTS, respectively.

Blood Variables as Potential Markers of Overreaching

The median (interquartile range) normal recovery values for creatine kinase, hemoglobin, testosterone, and cortisol for all 114 wrestlers according to competition weight classification are provided in Table 3. Exploratory data analysis using linear mixed modeling showed that only 5%, 44%, 43%, and 27% of the total variance in creatine kinase, hemoglobin, testosterone, and cortisol values, respectively, was explained by differences between wrestlers. We therefore obtained reference intervals for each overreached wrestler based on that wrestler's own normal recovery data. The diagnostic reference intervals for 15 of the 16 wrestlers who exhibited overreaching during the monitoring period are given in Table 4. Reference intervals for 1 wrestler were not calculated because she had fewer than 10 normal recovery values for each variable. Diagnostic sensitivity for FOR was 38%, 15%, 45%, and 18% for creatine kinase, hemoglobin, testosterone, and cortisol, respectively. Diagnostic sensitivity for NFOR was 29%, 33%, 26%, and 35% for creatine kinase, hemoglobin, testosterone, and cortisol, respectively. Specificity was 79%, 88%, 90%, and 82% for creatine kinase, hemoglobin, testosterone, and cortisol, respectively. Post hoc analysis using linear mixed modeling showed no mean differences in creatine kinase ($F = 0.5$, $P = .47$; log-transformed data), hemoglobin ($F = 3.8$, $P = .052$), testosterone ($F = 0.2$, $P = .62$), and cortisol ($F = 0.04$, $P = .85$) between monitoring periods when wrestlers were and were not diagnosed with FOR and NFOR.

DISCUSSION

The main aims of our study were to establish the incidence rates of FOR, NFOR, and OTS in elite female Chinese wrestlers during their normal training and competition schedules over an 8-year monitoring period and to investigate the utility of blood markers for identifying overreaching. Our main findings were that the incidences of FOR, NFOR, and OTS were relatively low except in the world-class wrestlers and that the blood markers creatine kinase, hemoglobin, testosterone, and cortisol were poor markers of overreaching.

Few authors have reported the incidence of FOR, NFOR, and OTS, and we are the first, to our knowledge, to report the incidence of FOR, NFOR, and OTS in female wrestlers.

Table 2. Wrestlers Experiencing Overreaching

Monitoring Period	Athletes Monitored, No.	Competition (No. Wrestlers Competing)	Type of Overreaching: Functional	Nonfunctional	Overtraining Syndrome
November 2003–March 2004	32	2004 Olympic Qualification Tournament (1)	1	0	0
April–July 2004	32	2004 National Qualification Tournament (8)	2	1	0
October 2005–September 2006	40	2006 Senior Asian Championship (7)	0	0	0
		2006 World Cup (7)	0	0	0
		2006 Senior World Championships (7)	1	1	0
October–December 2006	40	2006 15th Asian Games (4)	1	2	0
January 2007–January 2008	40	2007 National Qualification Tournament (12)	1	4	0
		2007 Senior Asian Championship (7)	0	0	0
		2007 National Qualification Tournament (12)	0	1	0
		2007 Senior World Championships (7)	1	2	0
		2008 World Cup (14)	0	0	0
February–July 2008	40	2008 Senior Asian Championship (7)	0	0	0
		2008 National Qualification Tournament 1 (7)	0	0	1
		2008 National Qualification Tournament 2 (6)	1	1	0
October 2009–May 2010	34	2010 World Cup (14)	0	1	0
		2010 Senior Asian Championship (7)	0	2	0
June–November 2010	36	2010 Junior Asian Championship (8)	0	1	0
		2010 Junior World Championships (8)	0	1	0
		2010 Youth Olympic Games (1)	0	0	0
		2010 Senior Combat Games (3)	0	0	0
		2010 Senior World Championships (7)	1	2	0
		2010 16th Asian games (4)	0	0	0
December 2010– November 2011	30	2011 World Cup (7)	1	1	0
		2011 Junior Asian Championship (8)	0	0	0
		2011 Senior Asian Championship (7)	1	0	0
		2011 Senior World Championship (7)	0	0	0
December 2011–May 2012	34	2012 Senior Asian Championship (7)	2	0	0
		2012 National Qualification Tournament (16)	0	2	0
		2012 Olympic Qualification Tournament 1 (1)	0	1	0
		2012 Olympic Qualification Tournament 2 (1)	0	0	1

Table 3. Normal Recovery Values for Blood Markers by Wrestlers' Competition Weight Classifications

Weight Classification, kg	No. Median (Interquartile Range): Creatine Kinase, U/L		Hemoglobin, g/L		Testosterone, ng/dL		Cortisol, μg/dL	
48	662	137 (89)	633	128 (14)	535	41.5 (23.2)	530	16.6 (5.1)
55	534	141 (96)	494	132 (11)	440	43.0 (21.1)	433	15.6 (5.1)
63	526	132 (82)	503	129 (10)	440	40.4 (20.0)	433	15.7 (4.6)
72	541	163 (124)	531	130 (14)	449	48.3 (23.5)	438	16.7 (4.8)
Total	2263	141 (95)	2161	130 (12)	1864	43.0 (22.8)	1834	16.1 (4.9)

Table 4. Diagnostic Reference Intervals for Blood Markers in Overtrained Wrestlers During the 8-y Monitoring Period

Wrestler Identification No.	Creatine Kinase, U/L	Hemoglobin, g/L	Testosterone, ng/dL	Cortisol, μg/dL
W10	93–719	99–138	8.2–64.3	6.9–22.9
W17	66–349	126–154	34.8–83.6	12.9–31.2
W24	93–775	117–135	25.0–54.4	9.7–21.3
W41	82–416	126–154	26.7–73.3	13.6–26.1
W49	114–877	113–139	16.4–57.9	5.8–19.9
W50	58–364	118–146	15.0–45.9	10.1–19.5
W63	59–482	119–140	30.7–77.7	9.2–20.0
W67	75–335	116–138	28.5–57.3	9.8–22.8
W68	106–483	115–169	18.5–105.2	10.0–22.1
W72	84–571	109–136	21.3–50.2	7.0–27.9
W74	68–372	126–144	18.6–50.1	11.6–21.0
W82	46–749	117–141	28.3–92.4	8.8–22.3
W84	63–423	116–149	14.2–60.7	13.7–20.4
W91	106–570	115–148	28.2–64.6	8.2–25.6
W111	75–589	125–142	20.7–61.4	7.0–24.7

The incidence of overtraining in different sports has shown wide variations, which seems due to the duration of assessment. Lower incidences of approximately 10% to 20% have been derived from single training seasons or cycles,[7,9] whereas higher incidences of approximately 60% have been observed in studies that assessed entire athletic careers.[8] This suggests that the incidence is positively associated with the duration of participation.[15,22] Approximately 10% of collegiate swimmers have been diagnosed as overtrained during a training season or cycle,[7] although incidences as high as 21% have been noted in some swimmers.[9] Conversely, incidences of overtraining as high as 60% and 64% have been reported for female and male elite distance runners during their careers.[8] Interestingly, the incidence was only 33% in nonelite women runners, the difference being attributed to the greater training distance undertaken by elite runners.[8] With respect to young athletes, approximately one-third have experienced NFOR or OTS, and the incidence was significantly higher in individual sports, in low–physical-demand sports, in females, and at the elite level.[6] In our elite female wrestlers, the incidence of NFOR was only 6.4% but was very high (69%) in the 13 wrestlers who had ranked in the top 3 in world championships. The training schedule for the Chinese national team focused on the wrestlers who were most likely to participate in international competitions. These world-class wrestlers often had higher training loads and greater monitoring periods than the others, many of whom were regarded as sparring wrestlers, and this likely explains the large difference in the incidence of NFOR for the 13 top-3 wrestlers compared with all the wrestlers. The greater demand to make weight and associated calorie restriction is also likely to be a contributory factor in the high incidence of NFOR in these 13 wrestlers.

The utility of blood markers as early-warning signs of overreaching has been extensively discussed but remains inconclusive.[28,29] Serum creatine kinase activity mirrors the mechanical muscular strain experienced in training in the preceding days and indicates the intensity and volume of exercise, particularly unaccustomed eccentric forms of exercise.[28] Creatine kinase is thus an important variable for determining muscular stress.[30] Follow-up studies of serum creatine kinase concentrations may primarily indicate an acute impairment in exercise tolerance, which may be prophylactic for OTS in the long term,[28] but has not been generally recognized as a diagnostic marker for NFOR or OTS in rugby league players,[10] triathletes,[21] cyclists,[12] or middle- and long-distance runners.[15] In our study, the diagnostic sensitivity for creatine kinase was 29% and the specificity was 79%, indicating that creatine kinase was not a useful marker of NFOR. Creatine kinase values can vary greatly among individuals: some athletes are regarded as low responders to physical training, with chronically low serum creatine kinase concentrations, and some athletes are regarded as high responders, with high values of the enzyme. This variability is thought to be related to the level of training, muscle size, and fiber type.[30] With this in mind, it seems reasonable that creatine kinase reference intervals should be based on the individual's own normal recovery data for monitoring training, as we did.

Decreases in serum hemoglobin concentration sometimes have been reported in overreached or overtrained athletes,[12,13,15,23] but other studies[10,21,31] have failed to find any change. In well-trained male cyclists, hemoglobin concentrations showed a significant decrease after a 2-week intensified training period.[12,23] Similar results also were found in experienced middle- and long-distance runners with OTS based on an increase in training volume for 4 weeks.[15] In 9 healthy, active young men, hemoglobin was not significantly different after a 9-week intensified aerobic training program and 3 weeks of recovery.[31] Eighteen semiprofessional rugby league players were randomly assigned to 2 pair-matched groups. One group completed 6 weeks of normal training and the other group was subjected to deliberate overreaching through intensified training. Hemoglobin was not significantly different after training in the groups.[10] Sixteen experienced male triathletes were divided into matched groups according to physical and performance characteristics and were randomly assigned to either normal or intensified training groups. Hemoglobin was measured at baseline, after 4 weeks of overload training, and after a 2-week taper. Hemoglobin concentration significantly decreased in both groups during the overload period, but no differences were evident between groups.[21] These results are consistent with our findings in that there was no difference in hemoglobin concentrations during periods when wrestlers were and were not diagnosed with NFOR. Although the specificity of 88% for hemoglobin was relatively high, the diagnostic sensitivity of 33% for diagnosing NFOR indicates that hemoglobin was a very poor marker of NFOR.

The documented response of both total and free testosterone concentrations in athletes who overreached is also contradictory. Testosterone decreased significantly in male swimmers and collegiate American football players during NFOR.[32] However, in male cross-country runners,[33] male cyclists,[16] well-trained male triathletes,[21] rugby league players,[10] and male adolescent handball players,[34] no differences in serum testosterone were observed between normal training and NFOR. These latter results are consistent with our findings of no significant difference in the testosterone concentrations of wrestlers during periods when they were and were not diagnosed with NFOR. At 26%, testosterone had the lowest diagnostic sensitivity for NFOR of the 4 blood markers, further supporting the premise that it is a poor marker of NFOR in elite female wrestlers.

Serum cortisol has been suggested as useful for monitoring the balance between intense training sessions and recovery time by indicating maladaptation to training, which leads to increases in fatigue and decrements in performance.[29,35] Although some investigators have suggested that decreased resting serum cortisol is a criterion for the diagnosis of OTS,[4,23,36–39] the results are controversial.[5] In endurance athletes, a significant decrease in plasma cortisol concentration was reported after a period of intensified training that resulted in a state of overreaching, although generally reduced performance was not found.[37] Another group[39] reported similar reductions in maximal cortisol levels in overreached athletes, with markedly reduced performance. In well-trained male cyclists, cortisol showed a significant decrease after a 2-week intensified training period.[23] Cortisol was lower in soccer players displaying performance decrements compared with controls, and cortisol levels were dissociated from adrenocorticotropic hormone levels only in athletes with performance decrements.[36] In another study[38] cortisol levels began to decline and submaximal exercise-induced increases in cortisol were blunted after 6 weeks of strenuous military training. In contrast, no significant differences in cortisol concentrations were observed in our wrestlers during periods when they were and were not diagnosed with overreaching. Like the other blood markers, cortisol had very poor diagnostic sensitivity. Our results are consistent with those of other studies in which no differences in resting plasma cortisol were observed in overreaching swimmers,[40,41] handball players,[34] well-trained male triathletes,[21] male collegiate American football players,[32] male rugby league players,[10] and male cyclists.[16] In a group of swimmers, salivary cortisol levels were significantly higher in underperforming athletes, and this correlated with depressed mood states.[4] This latter study highlights the need for more research to be conducted to establish whether a depressed cortisol concentration is a potential marker of overreaching.

In conclusion, the strength of our study is that we investigated overtraining in a relatively large cohort of 114 elite women wrestlers during their normal training and competition schedules. The main finding was that the incidence of overtraining was relatively low overall but very high in a subgroup of 13 world-class wrestlers. The other main finding was that the blood variables creatine kinase, hemoglobin, testosterone, and cortisol were not useful markers for the early detection of overreaching.

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