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Electrostimulation's Enhancement of Recovery During a Rugby Preseason

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Rugby preseason training involves high-volume strength and conditioning training, necessitating effective management of the recovery-stress state to avoid overtraining and maximize adaptive gains. ***Purpose:*** Compression garments and an electrostimulation device have been proposed to improve recovery by increasing venous blood flow. These devices were assessed using salivary testosterone and cortisol, plasma creatine kinase, and player questionnaires to determine sleep quality, energy level, mood, and enthusiasm. ***Methods:*** Twenty-five professional rugby players were assigned to 1 of 2 treatments (compression garment or a concurrent combination of electrostimulation and compression) in a crossover design over 2 × 2-wk training blocks. ***Results:*** Substantial benefits were observed in self-assessed energy levels (effect size [ES] 0.86), and enthusiasm (ES 0.80) as a result of the combined treatment when compared with compression-garment use. The combination treatment had no discernable effect on salivary hormones, with no treatment effect observed. The electrostimulation device did tend to accelerate the return of creatine kinase to baseline levels after 2 preseason rugby games when compared with the compression-garment intervention (ES 0.61; P = .08). ***Conclusions:*** Electrostimulation elicited psychometric and physiological benefits reflective of an improved recovery-stress state in professional male rugby players when combined with a lower-body compression garment.

Keywords: testosterone, cortisol, creatine kinase, compression

Rugby preseason training programs are designed to develop the physical requisites for competition and consist of a high volume of anaerobic and aerobic conditioning, as well as contact and resistance training. Such high-volume training has been associated with positive strength and body-composition adaptations but also increases in perceived fatigue in elite rugby union players.[1] The high training volume necessitates that athletes engage in effective strategies to optimize recovery and avoid the potential maladaptive physiological and psychological effects of overtraining.[2]

A range of interventions have been suggested to enhance aspects of athletic recovery, and research has attempted to ascertain optimal strategies. Compression garments have become popular with athletes and have been suggested to improve venous blood flow.[3,4] Static compression has demonstrated a clear positive relationship with increased blood flow that has been speculated as a myogenic response to a decrease in transmural pressure.[4] Compression garments have been shown to be as effective as cycling and contrast water-therapy strategies after competitive rugby matches using interstitial creatine kinase (CK) as an indicator of recovery[5] and have been reported to decrease perception of pain after intense exercise.[6]

In an alternative approach, electrically stimulated muscle contractions have also been shown to activate the skeletal-muscle pump and enhance venous return by up to 95%.[7] Despite some debate as to the relative importance of the mechanical pumping action of the musculature during exercise, there is no doubt that the muscle pump aids venous return to the heart due to increases in blood flow during the relaxation phase and localized vasodilation.[8] Electrostimulation of the peroneal nerve has been shown to augment venous blood flow in the legs of healthy volunteers.[9] As a consequence of its demonstrated ability to promote limb blood flow, electrostimulation has been assessed as a recovery strategy after exercise and has been shown to be more beneficial than both water-aerobic exercises and passive rest in reducing muscle pain in young soccer players.[10]

Monitoring psychometric variables has been suggested to detect early warning signs of overtraining more readily than various physiological or immunological markers,[11] with self-reported ratings of well-being providing an efficient means of monitoring both overtraining and recovery.[12] Indeed, high training loads are reported to cause sleep disturbances and mood changes,[13] as well

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as changes in basal hormone levels.[14] Self-reported measures of both mood[15] and fatigue[1] have previously been assessed in rugby players to examine training load and recovery effects.

Thus, the aim of this study was to assess the effectiveness of compression garments and an electrostimulation device (OnPulse) at assisting in recovery of professional rugby players during a preseason training period using psychometric, plasma CK, and salivary testosterone and cortisol monitoring. Due to the ethical dilemma of the use of a negative control in a professional training environment, the compression-garment group was intended to provide a benchmark for comparisons.

Materials and Methods

Participants

Sixteen professional rugby players (age 25 ± 3 y, height 188.1 ± 7.1 cm, body mass 104.0 ± 12.3 kg) volunteered to participate in this study. All had been selected from provincial sides to compete in the international Investec Super Rugby competition. Based on their medical history, all players were free of contraindications and gave their written informed consent. The local ethics committee approved the study protocol.

Protocol and Measurements

The players were assigned to groups (n = 8) matched as closely as possible by player position for each of 2 treatments (compression garment only or a concurrent combination of an electrostimulation device with the compression garment). This assignment was done to ensure an even distribution of players, as position-specific attributes have been identified.[16]

The recovery interventions were randomly assigned in a crossover design over 2 × 2-week blocks that comprised the first 2 blocks of the 6-week preseason training period described in Table 1. These two 2-week blocks were completed immediately before and after a Christmas break and included a high volume of resistance, aerobic, and anaerobic training sessions in addition to prescribed recovery sessions. A third 2-week block comprised a reduced volume compared with the first 2 blocks but involved 2 rugby games. Thus, in addition to monitoring during training alone, 2 games were monitored to assess the effectiveness of the 2 recovery strategies. The participants were instructed to wear their allocated treatment overnight if possible but for a minimum of 3 hours immediately after the completion of the final training session each day, Monday to Friday, and after the 2 rugby games. Daily texts and oral reminders were used, and compliance was assessed by verbal daily questioning and quantified via the written questionnaires.

Full-length lower-body compression garments (Adidas Tuned TechFit, UK) were individually fitted for each player. The electrostimulation device (OnPulse, FirstKind Ltd, UK) has a pulse current of 27 mA with 7 user-adjustable pulse widths and a repetition rate of 1 Hz. Each player was visually and orally instructed on the correct use of the electrostimulation devices (as per the

Table 1 Preseason Training Schedule

Block 1			Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Week 1	Loading	12:4:2*	15:4:7	4:0:4	15:4:8	4:6:2*	4:6:2	Off
		Duration, h	4.5	6.5	2	6.75	3	3	
	Week 2	Loading	12:4:7	8:4:2	4:10:2	6:6:0*	Christmas break (17 d)		
		Duration, h	5.75	3.5	4	3			
Block 2			**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
	Week 1	Loading	8:4:4*	8:8:2	0:4:4	4:8:2	8:8:4*	Off	Off
		Duration, h	4	4.5	2	3.5	5		
	Week 2	Loading	6:6:6*	6:12:2	0:0:8	6:6:6	6:10:2*	Off	Off
		Duration, h	4.5	5	2	4.5	4.5		
Block 3			**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
	Week 1	Loading	6:6:6:*	6:4:8	0:0:10	6:6:6	0:6:3	Game*	Off
		Duration, h	4.5	4.5	2.5	4.5	2.25		
	Week 2	Loading	0:10:3*	4:12:2	6:6:7	0:0:6	Game*	Off	Off*
		Duration, h	3.25	4.5	4.75	1.5			

Note: Loading describes the ratio of intense training sessions to moderate sessions to light sessions as prescribed by the trainers where each unit is equivalent to an assigned 15-min period. Thus, 12:4:2 describes a day where 3 h intense training (over 85% of predetermined maximum heart rate), 1 h moderate training (heart rate targeted to be between 60 and 85% of predetermined maximum heart rate), and 30 min light training (heart rate unlikely to exceed 60% of maximum) were prescribed. No single training session exceeded 90 min, with intersession rest periods ranging between 0 and 120 min. During the 17-d Christmas break, a fitness maintenance program was prescribed.

*Plasma collection.

manufacturer's guidelines) and individually required to demonstrate their proficiency in applying the devices, which were positioned on the posterior aspect of both knees to stimulate the common peroneal nerve and simultaneously activate the tibialis, peroneus longus, and lateral gastrocnemius muscles.

Each player self-selected a pulse width that was tolerable and produced visible ankle dorsiflexion and plantar flexion. This pulse width (duration) was selected from 1 of 7 available (70, 100, 140, 200, 280, 400, and 560 μs), and the setting was indicated by a flashing LED. The electrostimulation devices were applied to both legs, as previous research has demonstrated that stimulation of the ipsilateral leg muscles did not affect blood flow in the contralateral leg.[17] Thus, the combination treatment consisted of players wearing both the electrostimulation device and the compression garment concurrently, whereas players in the compression treatment only wore the compression garment.

Questionnaires were completed on Mondays, Wednesdays, and Fridays throughout the training blocks to assess subjective measures of sleep quality, energy level, mood, and enthusiasm using tailored 5-point Likert items. The Likert anchor points were assigned based on communication with senior players and the management group to ensure they would be well understood by this rugby cohort. The high, middle, and low anchors were sleep (*awesome, ok, shocking*), energy (*feeling pumped, average, poor*), mood (*feel great, average, not great*), and enthusiasm (*fizzing, average, not really up for it*). Individual items and a cumulative total of these 4 items were compared between treatments. Session rating of perceived exertion was used to quantitate training.[18,19]

Saliva samples were collected at 8 AM before training on Mondays, Tuesdays, Thursdays, and Fridays to assess cortisol and testosterone levels and calculate the testosterone-to-cortisol ratio. In an attempt to minimize contamination of the saliva samples, subjects were advised to avoid brushing their teeth, drinking hot fluids, or eating hard foods such as apples for the 2 hours before providing their sample. Sugar-free gum (Extra, Wrigleys, Auckland, NZ) was provided to assist with saliva stimulation. Saliva samples were stored at –20°C until assay.

Samples were analyzed using commercial ELISA kits (Salimetrics, LLC, USA) following the manufacturer's guidelines. The minimum detection limit for the testosterone assay was 2 pg/mL, with intra-assay and interassay coefficients of variation (CV) of 2.6% to 12.7%. Our cortisol assay had a detection limit of 0.3 ng/mL, with intra-assay and interassay CVs of 2.7% to 9.8%. Salivary sampling was selected because it is a stress-free method of sample collection and provides an accurate indication of fluctuations in the free-steroid concentrations in plasma.[20]

Blood samples were collected via finger prick, and samples were taken across the training blocks and before and 36 hours after matches (see Table 1 for collection time points) to assess plasma CK using an enzyme-linked immunosorbent assay.[21] Our CK assay had a detection limit of 0.09 ng/mL, with intra-assay and interassay CVs of 3.5% to 9.0%. Samples for each participant were analyzed in the same assay to eliminate interassay variance.

Statistical Analyses

Statistical significance was set at the $P \leq .05$ level. Changes within groups for saliva and enzyme measures and questionnaire values were analyzed using 2-way repeated-measures analysis of variance.[19] Comparisons between the groups were made using analysis of variance. The Tukey post hoc test was used to identify significantly different group means,[22] with hormone and enzyme data log-transformed to account for nonuniformity of residuals. Changes in the mean of each measure were used to assess magnitudes of effects by dividing the changes by the appropriate between-participants standard deviations. Magnitudes of the standardized effects were interpreted using thresholds of 0.2, 0.6, and 1.2 for small, moderate, and large effect sizes, respectively,[23] and were calculated at each time point. Standardized effects of between –0.19 and 0.19 were termed trivial. To make inferences about the large-sample value of an effect, the uncertainty in the effect was expressed as 90% confidence limits. The effect was deemed clear if its confidence interval did not overlap the thresholds for small positive and negative effects.

Results

Only 2 players reported that they failed to complete the required use of an intervention on a given day over the preseason program, and data for those players from those days were removed from the analyses. On average, treatment duration was 11.3 ± 1.9 hours for compression and 8.4 ± 3.4 hours for the combined treatments. Total training volumes in blocks 1 and 2 were similar ($P > .05$); however, session ratings of perceived exertion showed a greater loading at high intensities in block 1 (60.8%) than in block 2 (43.7%).

Substantial benefits of the combined treatment over compression were seen in the average perceptions of energy (ES 0.86) and enthusiasm (ES 0.80; Table 2). Furthermore, the likelihood of a nontrivial, beneficial effect of the combination treatment compared with the compression treatment was 91% for the energy measure and 89% for the enthusiasm measure. The respective likelihoods of a detrimental effect were 2% and 3%. As a result, the average cumulative total of the 4 Likert items was greater in the combination treatment than in the compression treatment (ES 0.50), with a 77% likelihood of a beneficial effect and a 5% likelihood of a negative effect.

The range for average morning levels for salivary testosterone was 97.8 to 153.7 pg/mL and for cortisol was 2.51 to 6.45 ng/mL. Testosterone levels decreased across block 1 (from 139.2 ± 37.7 to 114.6 ± 22.1 pg/mL; $P < .05$) and block 2 (from 157.7 ± 51.1 to 133.2 ± 32.9 pg/mL; $P = .08$). Cortisol levels also decreased across block 1 (from 5.15 ± 1.71 to 3.40 ± 1.63 ng/mL; $P < .01$) but not block 2 (from 6.33 ± 2.32 to 6.13 ± 1.99 ng/mL; $P > .05$). No significant differences in hormone data were observed between the treatments.

CK measures increased across block 1 (1.8 ± 0.7–12.5 ± 7.8 ng/mL; $P < .01$) and block 2 (1.8 ± 1.1–12.7 ± 8.1 ng/mL; $P < .01$); however, there was no difference between the treatments across the training blocks. Lower CK levels were observed 36 hours after rugby matches when the combination treatment was compared with the compression treatment (ES 0.61; $P = .08$; Figure 1).

Discussion

The combination of an electrostimulation device with a compression garment was effective at eliciting positive psychometric and physiological benefits in professional male rugby athletes over a preseason training period. The overall recovery differences were moderate and substantial in effect size compared with a compression intervention that has previously been demonstrated to be an effective recovery strategy.[3,5] Thus, the data suggest there is likely value in combining electrostimulation with a compression garment.

Electrostimulation that provides a near-isometric compression of the lower limb venous valve system has been reported to enhance blood flow more effectively than isolated contraction of the gastrocnemius.[9] In that study of healthy volunteers, Tucker et al[9] demonstrated that venous volume flow and mean peak venous velocity were increased approximately 200% at settings similar to the median stimulation levels of the device used in the current study (1 Hz, 200 µs, and 27 mA). Indeed, electrostimulation has been reported to enhance blood flow more than voluntary exercise performed at the same intensity.[24]

In athletic settings, compression garments have been shown to assist recovery by enhancing the removal of metabolic byproducts,[25] decreasing perception of soreness,[6] and decreasing interstitial CK.[5] Compression garments are reported to increase blood flow as the external compression increases tissue pressure, which in turn reduces transmural vascular pressure.[4] Indeed, Bochmann et al[4] demonstrated that external compression equivalent to a skin-surface pressure of 13 to 23 mmHg doubled forearm blood flow.

It has been reported that symptoms of overtraining can best be identified by self-analysis of sleep disturbances and alterations in mood state that are likely due to autonomic dysfunction.[26] Furthermore, intensive training has been demonstrated to negatively affect self-reported vigor and an energy index, and it has been recommended that more emphasis be placed on psychological recovery to avoid the possibility of maladaptive responses occurring at high training loads.[27] In a cohort similar to ours, Argus et al[1] reported moderate increases in fatigue over a 4-week rugby preseason. Our results suggest that the

Table 2 Self-Reported Psychometric Data across the Preseason Training Period, Mean ± SD

Treatment	Sleep quality	Energy	Mood	Enthusiasm	Sum of 4
Compression	2.4 ± 0.4	2.3 ± 0.3	2.6 ± 0.5	2.5 ± 0.3	9.8 ± 1.3
Combination	2.4 ± 0.3	2.6 ± 0.3*	2. 7 ± 0.3	2.8 ± 0.4*	10.5 ± 0. 9*

Note: Sleep quality, energy, mood, and enthusiasm were assessed using tailored 5-point Likert items. Sum of 4 is the average cumulative total of these 4 items.

*Substantially different from the compression intervention, effect size < .19.

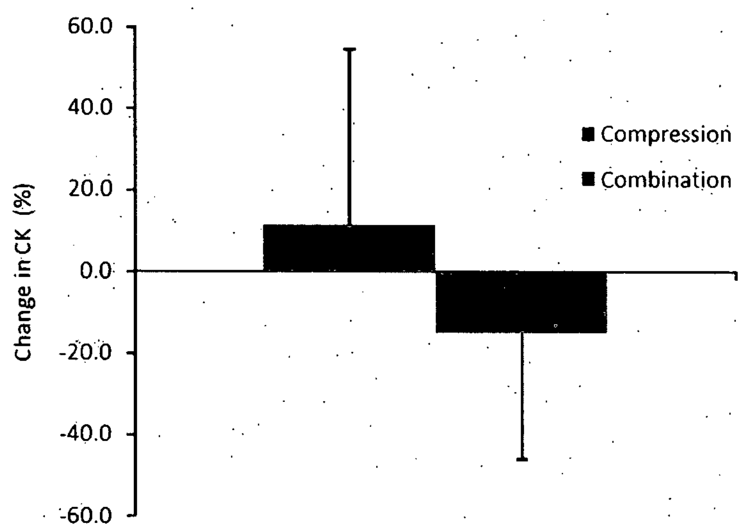

Figure 1 — Plasma creatine kinase (CK) changes 36 h after a rugby match. Compression, lower-body compression garment; combination, concurrent use of the lower-body compression garment and electrostimulation.

use of an electrostimulation device in combination with a compression garment, in a similar cohort, was capable of attenuating the self-reported perception of fatigue. Specifically, subjective energy and enthusiasm scores were improved when compared with the compression garment intervention alone. It is noteworthy that a loss of motivation has previously been identified as describing an overtrained state.[28] Thus, our data suggest that the combination of electrostimulation with a compression garment has additional psychometric benefits consistent with an improved recovery-stress state.

High training volumes have been associated with changes in basal hormone levels in elite rowers.[29] Indeed, decreases in serum testosterone have been observed in elite weightlifters in response to intense training periods.[30] Similarly, we saw decreases in salivary testosterone level across 2 high-volume training periods; however, no differences were observed between the treatments. The lack of changes observed in the current study may have been due to the hormonal data lacking the sensitivity to differentiate between the treatments.

The increases in CK observed in the current study reinforce previous research that has reported increases in CK across a 10-day preseason training.[31] Our CK data showed that the players using a combination of electrostimulation and a compression garment tended to recover more rapidly than those who used the compression garment alone after a rugby match. Rugby matches have been demonstrated to increase CK activity in interstitial fluid[5,32] and plasma.[33] These increases have been interpreted as indices of muscle damage, and associations have been demonstrated between increases in CK and intense muscle traumas.[32,33] Furthermore, decreases in CK after exercise are reported to represent an objective measure of recovery and have been used to assess the effectiveness of recovery strategies.[5,6] Thus, it is apparent that a combination of electrostimulation and a compression garment was more effective in accelerating recovery from a rugby match than the use of a compression garment alone, an intervention that has previously been demonstrated to enhance recovery.[5,6]

The total volume of training was not significantly different between the 2 training blocks ($P > .05$); however, a greater proportion of time was spent at higher intensity in block 1 than block 2. It is apparent that the different intensities of training performed are a limitation of the current research; further research should assess the effectiveness of the treatments under more controlled conditions. In addition, while the players were encouraged to maintain their daily posttraining routines, no attempt was made to quantify or standardize the time spent in a given posture that would likely affect the magnitude of blood-flow enhancement achieved as a result of electrostimulation. Despite the limitations of the field-based experimental data collected, this can also be viewed as adding ecological validity to the trial, as these data more closely reflect the real-world conditions under which athletes train and recover.

We also acknowledge that the duration and intensity of the electrostimulation intervention likely differed to some extent among players. However, players were instructed to individually adjust the device settings to produce forceful and visible ankle dorsiflexion and plantar flexion to account for desensitization and individual differences in electrical-stimulation thresholds.[34] Furthermore, quantification of total treatment duration revealed that the compression treatment was worn for approximately 3 hours longer than the combination treatment. Despite this shorter duration for the combination treatment, psychological and physiological measures were improved with it compared with the compression-only treatment. Also of note is the fact that this modality of nerve stimulation is quite different in the stimulation parameters from previously investigated direct muscle electrical-stimulation techniques used for recovery.[10,35] The electrostimulation method of the current study does, however, avoid the limitation of other procedures wherein limited and largely incomplete spatial recruitment of muscle fibers has been reported[24]

Practical Applications

The current study provides an insight into the training practices and physiological impact of a high-volume preseason training program in professional rugby players. The effectiveness of a novel electrostimulation device in improving self-reported psychometric measures was demonstrated and has the ability to enhance postmatch recovery for rugby players in an ecologically valid situation.

Conclusions

When worn during a preseason training period, the combined use of an electrical stimulation device with compression garments was more effective at eliciting positive responses in self-reported energy and enthusiasm than the use of a compression garment alone in professional rugby players. The electrostimulation device was also associated with reduced CK levels after rugby matches.

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