HORMONE RESPONSE TO JUMPING TESTS IN ADOLESCENT SPRINTERS

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Abstract:

The aim of this study was to investigate the effects of three different duration (1, 3 or 5 min) rest intervals on hormonal response in 10x10 hurdle jumping series. Eleven adolescent male sprinters and jumpers (16.2±0.9 years, height 170.5±7.9 cm, body mass 70.9±11.1 kg, body mass index 22.0±3.4 kg/m^2) participated in the study. An exercise session consisted of 10 two-legged jumps with arm swing over ten 76 cm high hurdles in 10 series which were separated by either 1-, 3- or 5-minute rest intervals. Venous blood samples were obtained before and after the session and cortisol (CORT), testosterone (TEST) and the growth hormone (GH) concentrations were analyzed. Mean jumping times over 10 hurdles using one (7.67±0.92 sec), three (7.44±0.66 sec) or five (7.14±0.54 sec) minutes of recovery were not significantly different from each other ($p>.05$). No significant changes were noted in CORT and TEST concentrations as a result of different exercise sessions. Compared with the initial value, GH increased rapidly ($p<.001$) after the jumping test with a 1-min rest interval. A negative correlation ($r=-.791$) was found between mean jumping time using 5-min rest intervals and changes in the TEST concentration. This study indicates that short jumping series with different length rest intervals do not significantly change TEST or CORT concentrations. However, the shortest rest interval (one minute) causes significant changes in GH concentration in adolescent sprinters and jumpers.

Key words: *anaerobic exercise, stress hormones, interval training, young athletes*

Introduction

Growth and maturation processes in humans are associated with profound modifications of different physical and psychological characteristics and several studies have evaluated the physiological performance in children and adolescents. However, compared to adults, in young individuals less data are available of the hormonal response to exercise-related stress, mainly due to ethical reasons (Di Luigi, et al., 2006). Since more and more children do different types of sports, more research on exercise-related endocrine system modification would appear to be essential. Physical activity can influence the endocrine secretory processes, and, in particular, acute physical exercise is able to sharply increase the serum concentrations of steroid hormones. Most of the data concerning hormonal responses to various types of exercise in adolescents is from the aerobic type of exercise (Boisseau, et al., 2000). However, there is much less data on high intensity exercise.

Different jumping exercises are performed in a training process in many sports. The number of stretch-shortening cycle muscle actions and the rest intervals are critical parameters influencing training adaptations (Edwards, 1981). The depletion of phosphocreatine (PCr) stores has been reported to occur during intense exercise in as few as five to seven seconds per attempt (Volek & Kraemer, 1993). Rest intervals of about three to four minutes are recommended for recovery of the phosphagen energy system during very high-intensity exercises, such as plyometric jumps (Robinson, et al., 1995).

Cortisol (CORT) is a catabolic hormone that increases in response to exercise at the intensity above 60% of maximal oxygen uptake (Banfi, 1998). In contrast, testosterone (TEST) is considered an anabolic hormone with multiple physiological functions. TEST is important in the growth and maintenance of the skeletal muscle (Zitzmann & Nieschlag, 2001). Kraemer et al. (1998) concluded that TEST increases linearly in response to exercise intensity with peak concentrations occurring at the end of exercise. In our previous study, 4x400 m interval runs with 5-min recovery suggested a different regulation of pituitary-adrenocortical activity (Jürimäe, Nurmekivi, & Jürimäe, 2004). There are no data available to describe the physiological

stress of very short jumping exercises. However, after 60 seconds of a Bosco's jumping test (Bosco, et al., 1996), CORT increased significantly in soccer players, and even more after a high vertical jump (VJ) performance. A significant positive relationship was found between fasting TEST levels and VJ performance in elite athletes (Cardinale & Stone, 2006).

Maximal anaerobic exercise is one of the most powerful physiological stimuli for growth hormone (GH) secretion. For example, a single 30-sec sprint on a cycle ergometer elicits a significant increase in serum GH (Stokes, 2003). In sprinters, after maximal 10x50 m exercise (4-minute resting interval), the highest increases in GH were found in those individuals who had the highest decline in maximal voluntary isometric contraction force of the knee extensors (Pullinen, MacDonald, Pakarinen, Komi, & Mero, 2005). A single bout of a 30-sec maximal sprint exercise increased GH more in the sprint-trained than in the endurance-trained athletes (Nevill, et al., 1996).

In resistance training, the duration of rest intervals between the sets appears to be an important variable that can directly affect training intensity and fatigue by altering the endocrine and metabolic responses (Fleck & Kraemer, 2004). Willardson (2006) concluded that for training muscular power, a minimum of three minutes of rest should be prescribed between sets of repeated maximal effort movements (e.g. plyometric jumps). Bottaro, Martins, Gentil, and Wagner (2009) found that the magnitude of acute GH response was greater with a 30-sec rest interval between sets compared to longer rest periods of 60 or 120 seconds. To our knowledge, no studies have investigated the influence of different periods of rest interval on hormonal adaptation to high intensity anaerobic exercise in male adolescent sprinters-jumpers. Since this type of exercise is widely used in relatively young children participating in a variety of sports, the information can be used in choosing the proper intensity of the exercise.

The aim of this cross-sectional study was to investigate hormonal response to three different durations of rest intervals (one, three or five minutes) during a hurdle jumping series. We hypothesized that the chosen exercises will be intense enough to significantly increase GH but not CORT and TEST. However, since a shorter recovery time between sets may cause higher hormone response, our aim was to determine the optimal recovery time consistent with optimal hormonal response.

Methods

A group of 11 adolescent male sprinters and jumpers participated in the study (mean age 16.2±.9 years, age ranging between 15 and 17 years; height 179.5±7.9 cm; body mass 70.9±11.1 kg, BMI 22.0±3.4 kg·m^2). All were members or member candidates of the Estonian national track-and-field team for their age group. To participate in the study they had to have training experience in track-and-field for at least 24 months and they must have been free of injuries during the last six months preceding the study. The participants had exercised at least five times per week during the last four to ten years and were preparing for the winter indoor competitions during the experimental period. The participants were asked not to change their dietary habits. All the participants were familiarized with the testing protocol, as they had been using this type of exercise frequently during their training process. All the participants and their parents signed an informed consent to participate in the study as approved by the Medical Ethics Committee of the University of Tartu, Estonia.

In this study, the participants were tested at an indoor track-and-field stadium three times with at least 24 to 48 hours between testing sessions. All tests were carried out at 4:00-6:00 p.m. to avoid circadian effects, and the testing time was kept identical for each participant. Body height (Martin metal anthropometer) and body mass (Medical balance, A&D Instruments Ltd, UK) were measured to the nearest 0.1 cm and 0.05 kg, respectively, and body mass index (BMI, kg·m^2) was calculated. One testing session (Figure 1) consisted of 10 sets of 10 consecutive two- parallel-legged jumps with arm swing (10x10 jumps) over 76 cm high hurdles. Three different testing sessions (10x10 jumps) were carried out on three different days, where the sets were separated by either 1-, 3- or 5-minute rest in-

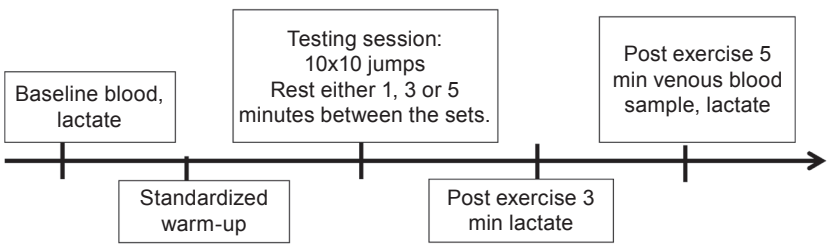

Figure 1. Graphical presentation of the study design. Only one recovery length was used during one testing session. The order of the used rest interval length was randomized.

tervals. Recovery sessions were designed to range from an incomplete short recovery of one minute to a five-minute full recovery. Testing sessions were performed on separate days at least 24 hours apart. Different recovery periods were applied in a randomized order within the sessions. Strong verbal encouragement was provided to athletes to complete all 10 jumps in a set as fast as possible and at maximal intensity. Time per one set and the total duration of 10x10 jumps was measured using an electronic timer. The rest interval started as soon as the athletes had finished each single set of 10 jumps. During rest intervals the athletes walked back to the start line and did easy walking or stretching exercises until the new jumping series began. Before the start of a testing session an individual standardized 15-20 min warm-up was used (running at slow pace, stretching exercises and 20-30 m sprints). The reliability of the used plyometric jump test was not measured. However, the jumping time of the first 10 jumps using different resting intervals (lasting one, three or five minutes) correlated highly to each other (r=.924-.980).

Sporttester Polar 725x (Polar Electro, Finland) was used for a continuous recording of the heart rate (HR) during the exercise sessions. Maximal HR was defined as the HR after the last (10) jumping set of the exercise session. Capillary blood samples were obtained from the fingertip before warm-up (baseline) and after three and five minutes of recovery after the exercise session (10x10 jumps). Blood LA concentration was analyzed enzymatically using Lange analyzer (Lange GMBH, Germany).

A 5-7 ml venous blood sample was obtained from the antecubital vein with the participants in the upright position before the warm-up and five minutes after the 10x10 jumping session. Plasma was separated and frozen at -20ºC for later analysis. CORT, TEST and GH concentrations were analyzed in duplicate using a chemiluminescent assay (Immulite 2000, DPC Los Angeles, USA). The intra- and inter-assay coefficients of variation for TEST, CORT and GH were ≤4.3% and ≤5.1%, ≤3.2% and ≤3.8%, ≤4.5% and ≤5.3%, respectively. Glucose (GL) concentration was measured using a Boehringer kit. Aliquots of the whole blood were analyzed for hematocrit after centrifugation at 12,000 rpm for 5 minutes and for hemoglobin using a micro-analyzer (Lange GMBH, Germany). Post-exercise changes in plasma volume were calculated using the formula of Dill & Costill (Dill & Costill, 1974).

Statistical analysis was performed with SPSS 15.0 for Windows. Means and standard deviations were calculated. Using Kolmogorov-Smirnov test our data were found to be normally distributed. Changes in dependent variables were analyzed using Student's *t*-test for paired samples. The Pearson's correlation coefficients between the dependent variables were used. Statistical significance was set at $p<.05$.

Results

Total time (warm-up not included) per 10x10 jumping exercise sessions was about 10 minutes, 28 minutes and 46 minutes for 1-, 3- or 5-minute resting intervals, respectively. Mean jumping times over 10 hurdles using 1-min (7.67±0.92 sec), 3-min (7.44±0.66 sec) or 5-min (7.14±0.54 sec) resting intervals were not significantly different from each other ($p>.05$). The differences in jumping times between the first and tenth set were relatively small (0.2-0.3 sec) ($p>.05$). Maximum HR was higher ($p<.01$) after the exercise session with 1-min rest intervals (161.2±13.6 beats·min-1) compared to the exercise sessions with 3-min (151.3±11.7 beats·min^{-1}) or 5-min (141.2±17.9 beats·min^{-1}) rest intervals. There were no differences in baseline blood LA concentrations ($p>.05$) (Table 1). The blood LA concentrations were higher ($p<.05$) at the third minute of the post exercise recovery compared with the fifth-minute post exercise recovery values in all cases. The 10x10-jump exercise session with 1-minute rest intervals caused significantly higher lactate concentrations after the whole session at both the third and fifth minute post exercise ($p<.05$; Table 1). The exercise session with 5-minute rest intervals caused significantly lower blood lactate values five minutes post exercise compared to the fifth minute post exercise values after the sessions with 1- or 3-minute rest intervals between sets (Table 1).

Table 1. Mean (±SD) blood lactate concentrations at baseline before the testing session and three and five minutes after the exercise session (three and five minutes post)

Rest interval	Baseline	Three minutes post	Five minutes post
One minute	2.47±0.98	6.25±2.01*¤	4.67±2.66*¤
Three minutes	2.37±0.53	5.61±2.01*	4.01±1.13*#
Five minutes	2.24±0.59	5.20±2.40*	3.54±1.10*#$

Legend: * – statistically significant change compared to baseline value ($p<.05$); # – significantly different from the value obtained using 1 minute rest interval ($p<.05$); ¤ – significantly different from the values using 3- or 5-minute rest intervals ($p<.05$); $ – significantly different from five minutes post exercise using 1- and 3-minute rest intervals ($p<.05$).

There were no significant pre-test differences in the measured hormonal parameters (Table 2) and all the hormonal concentrations were within acceptable clinical ranges (McMurray & Hackney, 2000). No significant changes were found in the CORT and TEST values as a result of different lengths of rest intervals. GH increased only after the jumping sessions with 1-min ($p<.001$) and 3-min ($p<.05$) rest intervals. Blood GL concentration increased significantly after all three exercise sessions (Table 2). However, before the start of the 1-min rest interval session, the GL concentration was significantly ($p<.05$) lower than before the 3- or 5-minute rest interval sessions.

Table 2. Hormone and glucose concentrations (Mean±SD) before and after each testing session

	Before jumping	After jumping	p
Cortisol ($mmol \cdot l^{-1}$)			
10x10 jumps (1-min rest)	271.5±94.1	290.6±113.2	>.05
10x10 jumps (3-min rest)	313.9±167.9	243.9±64.2	>.05
10x10 jumps (5-min rest)	330.2±112.6	265.6±120.6	>.05
Testosterone ($nmol \cdot l^{-1}$)			
10x10 jumps (1-min rest)	12.3±3.7	13.9±5.8	>.05
10x10 jumps (3-min rest)	13.1±4.2	12.3±5.8	>.05
10x10 jumps (5-min rest)	13.0±4.9	12.5±6.1	>.05
Growth hormone ($\mu l \cdot U \cdot ml^{-1}$)			
10x10 jumps (1-min rest)	5.5±10.0	51.6±54.3	<.001
10x10 jumps (3-min rest)	5.6±7.3	32.1±53.0	<.05
10x10 jumps (5-min rest)	3.2±4.6	24.1±25.8	>.05
Glucose ($mmol \cdot l^{-1}$)			
10x10 jumps (1-min rest)	4.2±0.5	5.3±0.5	<.000
10x10 jumps (3-min rest)	5.1±1.0	5.6±0.5	<.05
10x10 jumps (5-min rest)	4.9±0.8	5.6±0.5	<.05

As a rule, no significant correlations were found between the changes in individual hormonal concentrations and jumping time or exercise session intensity (HR and blood LA concentrations) parameters. However, a positive correlation was found between blood LA concentration obtained five minutes after the exercise using 5-min rest protocol and the changes in CORT ($r=.725$; $p<.05$) and GH values ($r=.720$; $p<.05$). A similar but negative correlation ($r=-.791$) was found between the mean jumping time of the exercise session using 5-min rest intervals and changes in TEST concentration.

Discussion and conclusions

The number of jumps within a set and the number of sets of the jumps (10x10) were chosen as a typical type of training used for improving speed and power in sprinters and jumpers. However, in practice used rest intervals are usually structured to be rather long between the sets assuming a disturbance of homeostasis. In this study we found that the shortest rest interval (one minute) was not sufficient to increase physiological intensity parameters (HR and blood LA) to the threshold level necessary for increasing CORT and TEST concentration. However, the shortest rest interval caused an increase in GH concentration.

Heart rate during jumping sets was between 140-160 $beats \cdot min^{-1}$ and blood LA concentration between 5-6 $mmol \cdot l^{-1}$ after the exercise sessions. However, in male adult sprinters, after 10x50 m sprint with four-minute in-between recovery, blood LA concentration was increased to 13.8±2.1 $mmol \cdot l^{-1}$ (Pullinen, et al., 2005), or during 10 times 6-second sprints with 30-second rest intervals, blood LA increased to 13.96±1.70 $mmol \cdot l^{-1}$ in male adult sprinters (Brooks, et al., 1990). However, Buchheit et al. (2009) concluded that in team sport athletes, six repeated 4-second sprints increased blood LA to about 13 $mmol \cdot l^{-1}$, but the mean HR was about the same as in our study (155-160 $beats \cdot min^{-1}$). HR and blood LA did not correlate between each other and exercise session time was not related to HR or blood LA concentration in this study. It is known that HR is not the best measure of exercise intensity when exercise is of a short duration. It is difficult to explain low LA concentrations in our study after the jumping series. One possible explanation could be that during very high intensity interval training, subjects of that age may need shorter resting periods than adults to stimulate lactic acid production (Bar-Or, 1995).

The blood concentration of CORT response requires a threshold exercise intensity above 60% of

maximal effort (Banfi, 1998). Some studies have indicated the possibility that high-intensity anaerobic exercises may even suppress CORT response (Barwich, Rettenmeier, & Weicker, 1982). In our study, the mean CORT concentration was not changed significantly (see Table 2). Unchanged CORT levels could suggest that even the shortest rest interval (one minute) was not sufficient to increase the whole body stress, as supported also by relatively low blood LA concentrations.

Using individual analysis, the significant intra-individual variations in CORT of ±25 $mmol \cdot l^{-1}$ were found (Viru, Karelson, & Smirnova, 1992). In our study, the protocol using 1-min rest intervals caused individual increases in CORT concentration values in general, but in the protocols with longer resting intervals a decrease was seen. As a rule, exercise intensity parameters such as HR and blood LA concentrations after different exercise protocols, do not correlate significantly with measured CORT concentrations. However, in the exercise session with 5-minute rest intervals, the changes in CORT correlated significantly ($p<.026$) with the changes in blood LA concentration at the fifth minute of the post exercise recovery ($r=.662$). The lack of correlation between HR and hormonal data can be explained by the lag period in HR response to high intensity short-duration exercise. HRs in general do not reach maximal level if a short exercise protocol is used. On the other hand, due to significant anaerobic energy utilization during short duration maximal work, lactate concentration increases in the blood. Maximal blood lactate has been found to be directly related to the increased testosterone levels (Falgairette, et al., 1996). On the other hand, we found that this type of exercise might not be sufficient to elicit stress-hormone levels. Similarly, a recent study by Derbré et al. (2010) indicated that using short-term sprint exercise might not be sufficient to cause significant changes in testosterone concentration.

Typical acute anabolic hormonal response to a maximal anaerobic interval training session is characterized by an increased level of post-exercise TEST in adults (Fry, Kraemer, & Ramsey, 1998). In contrast, the mean TEST concentration was not significantly changed after the different exercise sessions in our study (see Table 2). Post-exercise HR and blood LA concentration were also not related to changes in TEST concentrations. Kraemer et al. (1991) concluded that blood LA increase was accompanied by a TEST increment after heavy resistance exercise. However, in the current study both LA and TEST concentrations were relatively low (see Table 2), which could further suggest that the used exercise protocols caused little stress to our athletes.

In our study, there were no significant relationships between TEST and CORT concentrations. Previously, Brownlee, Moore, and Hackney (2005) concluded that there was a significant relationship between CORT and TEST during the recovery after exercise. CORT and TEST adaptations to very short (7-8 seconds) anaerobic jumping exercise sets need more studies for clarification. However, several speculations exist. First, the total duration of the exercise was too short to influence CORT and TEST concentration in our study. Secondly, a positive relationship of explosive jumping performance with the percentage of fast twitch fibers in the *musculus vastus lateralis* (Bosco, Komi, Tihanyi, Fekete, & Apor, 1983) and the level of TEST in young athletes (Mero, Jaakkola, & Komi, 1990) has been found. Thirdly, CORT and TEST are formed in the same cascade of reactions in the adrenal cortex (Kroboth, Salek, Pittenger, Fabian, & Frye, 1999). This means that when the adrenal gland is stimulated to produce CORT, it is possible that some TEST is also produced.

Several studies have demonstrated that exercise of sufficient intensity and duration elicits increase in circulating GH concentrations (Nevill, et al., 1996). Compared with a different intensity endurance exercise (Jürimäe, Jürimäe, & Purge, 2001) there is little information about GH reactions to a very short anaerobic bout of exercise. The GH response to exercise depends on the duration and intensity of the exercise bout and relatively short post-session sampling time may have precluded a proper assessment of full GH response. Sprint exercises during 30 seconds on a cycle ergometer have been shown to increase GH concentration significantly (Stokes, 2003). However, those exercise protocols were longer than the ones used in our study. In our study GH concentration increased after the exercise protocols with 1- and 3-minute rest intervals (see Table 2). Acute GH responses to anaerobic lower body resistance exercise appear greater with 30-second intervals between sets compared with 60- or 120-second rest intervals in trained females (Bottaro, et al., 2009).

Both aerobic and anaerobic exercises that stimulate GH secretion involve a high metabolic demand. Eliakim, Oh and Cooper (2000) demonstrated a small, but still significant GH response to exercise input that was perceived as difficult by the subjects, but did not elevate circulating lactate levels. This suggests that other features like individual exertion may also activate the GH axis which can be seen by relatively high SD values in post exercise GH concentrations. Finally, in our study, the changes in GH caused by the 5-minute resting periods jumping sets correlated significantly with blood LA concentrations in the 3rd and 5th minute of the post exercise recovery ($r=.717$ and $r=.707$, $p<.01$), respectively.

This study has some limitations. A non-exercise control trial was not performed and the sample size

was homogeneous but relatively small. The tests in our study were performed in the afternoon which might influence basal hormone concentrations in connection with the phase of circadian rhythm and the post-exercise sampling time might have missed the peak GH response. However, to overcome this limitation, each subject was tested at the same time of the day during three different exercise sessions.

In conclusion, this study indicates that very short, high-intensity jumping exercises (10x10 jumps) in adolescent sprinters and jumpers do not affect TEST or CORT concentrations when separated by different rest intervals, but do significantly increase GH concentration when sets of 10 jumps are separated by the shortest (1 minute) rest intervals.

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HORMONSKI ODGOVOR NA SKAKAČKI TEST U SPRINTERA ADOLESCENATA

Cilj je ovoga istraživanja bio utvrditi učinke intervala odmora različita trajanja (1, 3 i 5 minuta) između 10 serija od po 10 skokova preko prepona na hormonske odgovore jedanaestorice sprintera i skakača adolescenata (16,2±0,9 godina, tjelesna visina 170,5±7,.9 cm, tjelesna masa 70,9±11,1 kg, indeks tjelesne mase 22,0±3,4 kg/m^2). Protokol vježbanja sastojao se od 10 serija sunožnih preskoka sa zamahom rukama preko 10 prepona visokih 76 cm s odmorima od 1, 3 ili 5 minuta između serija. Uzorci venske krvi uzimani su prije i nakon vježbanja te su analizirane koncentracije kortizola (CORT), testosterona (TEST) i hormona rasta (GH). Prosječno je izvođenje jedne serije (10 skokova) trajalo 7,67±0,92 sekunda s odmorom od jedne minute, 7,44±0,66 sekunda s odmorom od 3 minute i 7,14±0,54 sekunda s odmorom od 5 minuta. Nije bilo statistički značajnih razlika između njih na razini od p>,05. Nisu zabilježene značajne promjene u koncentracijama CORT i TEST nakon provedenih različitih protokola vježbanja. U usporedbi s inicijalnim mjerenjima, koncentracija GH je naglo rasla (p<,001) nakon skakačkoga testa provedenoga s jednominutnom pauzom između serija. Negativna korelacija (r=-,791) zabilježena je između prosječnoga vremena skokova s petominutnom pauzom između serija i promjena u koncentraciji TEST. Ovo istraživanje pokazuje da kratkotrajne serije skokova s različitim trajanjem odmora među njima ne izazivaju značajne promjene u koncentracijama TEST i CORT, ali u protokolu vježbanja s najkraćom pauzom (jedna minuta) dolazi do značajnih razlika u koncentraciji GH u sprintera i skakača adolescenata.

Ključne riječi: *anaerobna vježba, stres hormoni, intervalni trening, mladi sportaši*