Effect of Different Exercise Stressors on Soldier's Psychophysiological Response and Marksmanship

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Research

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Abstract

Background: Authors have proposed that depending on the type of fatigue, either central or peripherical, as well as previous training and experience, shooting impairment may occur in different gradients. However, the effects of different stressor stimuli on fine motor skills as shooting is yet not fully understood.

Methods: The present research aimed to analyze the effect of endurance and resisted physical stressors on the psychophysiological response and pistol marksmanship of soldiers, and the possible differences by gender and weigh. Variables of heart rate, isometric hand strength, rated of perceived exertion and pistol marksmanship were analyzed in 86 soldiers in basal, endurance and resisted stress protocols moments.

Results: Isometric hand strength, HR and RPE were significantly higher in both resisted and endurance physical stress protocols than in basal sample. Gender differences were seen, among strength, cardiovascular and RPE values. Also, soldiers with larger BMI presented significantly higher isometric hand strength and higher marksmanship in all moments evaluated.

Conclusions: An endurance stress protocol produced a higher cardiovascular and perceived exertion than a resisted one, not affecting hand strength, shooting heart rate and marksmanship. Females presented lower hand strength marksmanship and higher rated of perceived exertion and heart rate during the endurance and resisted stress protocols than males. Overweight soldiers have higher heart rate during both protocols, higher hand strength and marksmanship, and similar hear rate while shooting than normoweight soldiers.

Introduction

The effects of different stressor stimuli/contexts on fine motor skills is an area with wide applications but that not highly developed. Stress effects may differ regarding the characteristics of the stressor stimuli. In the case of physical exercise, the intensity, duration and type of exercise have a direct impact either in fine and gross motor skills [1]. Authors found how after a bout of high-intensity, lower-body resistance training passing accuracy were decreased [2]; after cycling in an ergometer at 100% of maximal capacity, significant attenuation on reaction times were found, nor like at lower intensities (70%) [3], suggesting an inverted-U function between exercise intensity and motor control. Specifically, in combat previous researchers found no effect on marksmanship despite the increased combat stress, neither with rifle and pistol independently of the caffeine ingestion [4, 5]. The physiological mechanisms underlying the decrease of performance on fine motor skills may be related to: i. the accumulation of hydrogen ions, which affect glycolytic enzymes due to low Ph, impairing the ATP production and compromising the contractile capacity of the muscle [6]; ii. the high inorganic phosphate concentration, which inhibits Ca + + reuptake increasing its concentration in the sarcoplasm and hindering muscle contraction; and iii. the ammonia concentration, which is related to the affection of neurobiological processes, affecting the quality of neural connections and electrical activity of the muscle [7] .In addition, all these acute metabolic responses are directly modulated by the intensity and type of exercise [8] .Related to shooting accuracy and marksmanship, previous authors showed that high intensity exercise affected central aspects of shooting performance, shooting accuracy, shooting precision, and stability of hold, being accentuated when shooting in standing position, compared with shooting in prone position [9].Acute protocols designed to fatigue the upper body flexor muscle groups (muscles involved in stabilizing and supporting a firearm), such as lifting, climbing, and pulling, presented significant decreases in rapid fire rifle shooting performance in the standing position in soldiers immediately after these exercises [10].In this line, independently of the type of exercise (concentric, eccentric, or a combination of both) or the location (knee, ankle, or entire lower extremity), acute fatigue may induce a loss of stability [11].This fact, directly affect postural, standing and gun stability, key factors connected to rifle shooting accuracy [12] since body sway and imbalance has been directly correlated with poor shooting score [13, 14] .Superior shooting performance requires good postural balance, as well as, an ability to steady the gun while aiming [12] .However, the effect of different acute stress exercise-induced peripheral fatigue in fine motor skills as shooting, is yet not well documented. Most of the studies have focused either in soldiers or experienced soldiers, showing how lower fitness level, experience and training increased the fatigue and decrease marksmanship [15, 16] .In addition, previous studies were focus in rifle, showing lower research in pistols, leading to greater muscular fatigue due to the farer center of mass to the shooters body and the increase in joints angle [17] .Thus, we proposed the present research with the principal aim of to analyze the effect of endurance and resisted physical stressors on the psychophysiological response and pistol marksmanship of non-experienced soldier shooters. As a second aim, we aimed to analyze differences by gender and weigh. We hypothesized that i. resisted physical stressor would produce a higher psychophysiological stress response, decreasing the marksmanship more than the endurance exercise stressor; ii. Soldiers with higher body mass index (BMI) would present higher psychophysiological response and lower marksmanship; iii. There would be gender differences in the psychophysiological stress response and marksmanship.

Materials And Methods

Participants

A total of 86 new infantry cadets soldiers (23.6 ± 3.7 years; 175.8 ± 9.1 cm; 71.3 ± 8.7kg; 23.1 ± 2.2 BMI) were analyzed. Inclusion Criteria was: Age between 18 and 30. Exclusion Criteria were: Any professional nor amateur experience in the use of firearms and shooting, presence of any medical condition or injury that would be a limiting factor for intense physical activity and the use of firearms (e.g. cardiovascular diseases) at the moment or during the protocol, intake of any dietary supplement, stimulants or other ergogenic aids. Soldiers were informed of the characteristics of the study and the potential risks derived from those who were exposed. All the procedures were conducted following the Helsinki Declaration (as revised in Brazil, 2013), all the soldiers filled an informed consent form previous start the research and all the procedures were approved by the University Ethic Committee and the commanding military command center.

Methods

Procedures

Before the research started all the soldiers received instructions/familiarization regarding the protocol and tests. Then 3 days of evaluation were distributed as it follows: 1º Day: basal sample of all the variables measured in the study; 2º Day: 48h after, soldiers performed randomly an endurance or resisted physical stress protocol; 3º Day: 48h after, soldiers performed the remaining protocol.

For both physical stress protocols, soldiers conducted a warm-up composed by:

i. 2 min of joint mobility
ii. 5 min of light aerobic running (50–60% Maximum Heart Rate)
iii. 2 series of 20 m of progressive running intensity

After warm-up, soldiers performed the physical stress protocol, which were supervised and encouraged by sport science professionals:

Resisted Physical Stress Protocol

-20 sets of burpees at maximum intensity

Endurance Physical Stress Protocol

-5 min maximal running test in a track field.

Prior to the research, body weight was assessed with a SECA scale model 714 with a precision of 100 grams (range 0.1–130 Kg), located on a flat and smooth surface and calibrated at zero. Soldiers were barefoot and with minimal clothes. Once located in the centre of the platform, they remained without its body being in contact with surrounding objects, with the weight evenly distributed on both feet facing forward. Height, with a SECA scale model 714 with a precision of 0.1 mm (range 60–200 cm). Soldiers stood up, barefoot with the head oriented in the Frankfurt plane. Arms on both sides of the trunk and fully extended with palms touching the external face of the thighs, heels together touching the lower end of the vertical surface with the inner edge of the feet, occipital area, scapular, buttocks, posterior face of the knees and calves touching the vertical surface of the anthropometer.

Before and after the exercise stress protocols, we measured:

-Rating of perceived exertion (RPE), 6–20 scale.

-Isometric hand-grip strength using a TKK 5402 dynamometer (Takei Scientific Instruments CO. LTD). Each soldier grip strength was measured on the shooting hand. Soldier were standing with 0 degrees of shoulder flexion, 90 degrees of elbow flexion and the forearm in neutral. Idem, was done pre post and among series.

-Heart Rate (HR) measured before and during the entire protocol by a Polar V800 HR monitor (Kempele, Finland). -Shooting performance was measured by the sum of three airsoft pistol shoots to a target at a distance of 7 m, following procedures of previous research [4, 5]

Statistical analyses

To analyze the data, we used the SPSS statistical package (version 24.0; SPSS, Inc., Chicago, Ill.). Means and standard deviation (SD) were calculated using traditional statistical techniques. Normality and homoscedasticity assumptions were checked with a Kolmogorov-Smirnov test. To analyze differences between pre and post a T-test was administer, and to analyze differences between experimental groups (gender and BMI) and differences between moments of evaluation, an ANOVA test was conducted since variables presented a parametric distribution.

Results

The results are reported as mean ± SD. Isometric hand strength, HR and RPE were significantly higher in both Resisted and Endurance physical stress protocols than basal sample (Table 1).

Table 1
Psychophysiological parameters analyzed before and after the physical stress protocols.

	Basal	**Resistance Training**	**Endurance Training**	**F**	**P**	**η2**	**Moment comparison**
Isometric Hand Strength	42.8 ± 8.4	44.9 ± 6.4	42.7 ± 2.1	8.481	.001	.239	2 > 1
Marksmanship	12.8 ± 9.5	14.5 ± 10.6	15.2 ± 10.1	1.844	.168	.068	-
Heart rate during protocol	-	166.1 ± 13.3	178.9 ± 11.7	68.156	.013	.711	3 > 2
Shooting Heart Rate	90.3 ± 17.5	125.2 ± 19.0	124.3 ± 17.6	50.122	.000	.650	2 > 1; 3 > 1
Rated of Perceived Exertion	6.6 ± 1.1	15.2 ± 2.0	16.8 ± 1.8	739.846	.000	.965	3 > 2 > 1; 3 > 1

According to gender differences, males present significant higher isometric hand strength at all moments evaluated. HR at shooting at Basal and Endurance physical stress protocol of females was statistically higher than males. Female RPE was higher than males at Resisted and Endurance physical stress protocols (Table 2).

Table 2
Psychophysiological gender differences of the parameters analyzed before and after the physical stress protocols.

		Basal (1)	Resistance based exercise (2)	Endurance Based exercise (3)	F	P	η2	Moment comparison
Male	Isometric Hand Strength	44.8 ± 7.8	46.3 ± 6.2	43.9 ± 9.5	3.973	.026	.153	2 > 1
	Marksmanship	13.6 ± 9.5	16.0 ± 10.8	15.7 ± 10.7	1.940	.156	.081	-
	Heart rate during protocol	-	165.8 ± 9.2	178.9 ± 6.1	71.012	.021	.781	3 > 2
	Shooting Heart Rate	87.7 ± 17.0	128.4 ± 16.0	121.6 ± 16.5	65.007	.000	.747	2 > 1;2 > 3;3 > 1
	Rated of Perceived Exertion	6.6 ± 1.1	14.9 ± 2.0	16.5 ± 1.8	604.148	.000	.965	3 > 2 > 1; 3 > 1
Female	Isometric Hand Strength	33.4 ± 2.4 (.000)	38.2 ± 1.0 (.000)	36.9 ± 2.1 (.025)	53.399	.000	.930	3 > 1; 2 > 1
	Marksmanship	9.2 ± 9.1 (.011)	7.4 ± 5.5 (.018)	13.2 ± 7.3 (.024)	2.533	.141	.388	-
	Heart rate during Protocol	-	174.4 ± 8.2 (.011)	191.2 ± 7.1 (.006)	71.231	.000	.961	3 > 2
	Shooting Heart Rate	102.6 ± 15.0 (.014)	113.6 ± 27.1	136.6 ± 17.9 (.014)	69.514	.000	.946	3 > 1; 3 > 2
	Rated of Perceived Exertion	6.6 ± 1.2	16.2 ± 1.8 (.009)	18.2 ± 1.0 (.007)	392.302	.000	.990	3 > 1; 2 > 1

Between parenthesis significant differences ($p \leq 0.05$) between male vs female.

Soldierss with larger BMI (BMI ≥ 25 Overweight) presented significantly higher isometric hand strength at Basal and Resisted physical stress protocol than soldierss with lower BMI (BMI < 25). Soldierss with larger BMI also presented higher marksmanship in all moments evaluated (Table 3)

Table 3
Psychophysiological body mass index differences of the parameters analyzed before and after the physical stress protocols.

.		Basal (1)	Resistance based exercise (2)	Endurance Based exercise (3)	F	P	η2	Moment comparison
BMI < 25	Isometric Hand Strength	41.7 ± 3.5	43.7 ± 7.0	42.9 ± 7.7	1.197	.318	.238	-
	Marksmanship	11.4 ± 9.7	12.4 ± 10.6	12.5 ± 8.8	.380	.686	.019	-
	Heart rate during protocol	-	163 ± 8.5	178 ± 7.2	67.145	.032	.631	3 > 2
	Shooting Heart Rate	91.8 ± 15.2	125.9 ± 14.7	126.8 ± 17.2	28.322	.000	.685	1 < 2; 1 < 3
	Rated of Perceived Exertion	6.5 ± 1.0	14.7 ± 1.9	16.8 ± 1.5	910.743	.000	.979	1 < 2; 1 < 3; 2 < 3
BMI ≥ 25	Isometric Hand Strength	44.5 ± 2.8 (.019)	48.5 ± 5.5 (.011)	39.7 ± 12.9	22.960	.000	.793	1 < 2
	Marksmanship	16.8 ± 7.8 (.001)	20.8 ± 7.7 (.009)	23.4 ± 9.8 (.000)	2.169	.157	.266	-
	Heart rate during protocol	-	171 ± 9.7 (.031)	188 ± 9.1 (.021)	79.256	.038	.720	3 > 2
	Shooting Heart Rate	92.7 ± 23.5	122.2 ± 24.3	118.4 ± 16.9	3.996	.047	.400	1 < 2; 1 < 3
	Rated of Perceived Exertion	7.0 ± 1.3	16.4 ± 1.7 (0.007)	18.8 ± 2.4 (0.021)	112.325	.000	.949	1 < 2; 1 < 3

Between parenthesis significant differences ($p \leq 0.05$) between BMI < 25 vs BMI ≥ 25.

Discussion

The present research aimed to analyze the effect of endurance and resisted physical stressors on the psychophysiological response and pistol marksmanship of non-experienced soldier shooters. Our hypotheses were partially completed since i. There were no significant differences stress protocols in the psychophysiological stress response neither marksmanship. ii. Similar psychophysiological response was found independently of the BMI, but soldiers with larger BMI presented higher marksmanship values. iii. There were gender differences in the psychophysiological stress response and marksmanship.

The cardiovascular response monitored at basal time was higher than the considered standard for the population evaluated (60–70 bpm) [18] .This was consistent with an anticipatory anxiety response, a defense organic response modulated by the activation of the sympathetic nervous system that prepare individuals for any uncontrolled or new stimuli [19] .Previous authors reported a significant increase in the heart rate from standing resting position to an standing position firing a gun, in line with the results obtained in the present research [20] . Cardiovascular response has a direct impact on fine motor skills as shooting, the higher HR shortens the diastolic phase and increases the systolic one, increasing body tremor [21],which in addition to the one produced by physical activity, marksmanship could be compromised [22, 23].After resisted and endurance physical stress protocols we found a significant increase in the cardiovascular response at shooting (38.6% and 46% respectively), however marksmanship was not affected, suggesting no negative effect of shooting HR and fine motor skills. In this line, previous authors obtained similar cardiovascular results, without a marksmanship compromise in archers [22] and pistol shooters [24] .The lack of significant differences in marksmanship between the two stress protocol highlighted the no effects of peripheral fatigue on shooting performance. There are three possible hypotheses which would explain this: i) Soldiers performed both resisted and endurance physical stress protocols with an optimal arousal level [25, 26] ,in accordance with the Inverted-U hypothesis which predicts that performance is best at a moderate optimal level and becomes progressively worse with either increases or decreases in arousal, and comes to confirm that incorporating psychological factors in training (e.g. pressure), may enhance performance [27, 28] ;ii) Since soldiers have none previous experience and despite performing a familiarization, as consequence of low total acquired experience, fatigue did not affect their marksmanship values; iii) Among the familiarization, breathing and holding techniques were taught to the soldiers, which is essential to attenuate the postural tremors created by possible high HR at the moment of shooting, technique which has proven essential for rifle or pistol ,[15] and arch [22], the use of these techniques could be another possible explanation. The ability to stabilize a gun is crucial for performance in pistol shooting, being related to the shooter's muscular strength [29]. The maintenance of isometric hand strength can play an important role in this fact, highlighting the importance of physical fitness for athletes and professionals that have to use fire weapons (as biathlon athletes, or police and military respectively). Previous authors proposed integrated operative high intensity interval training as one of the best training tools for this aim, since it allow soldiers to improve both, muscular and cardiovascular performance, two factors directly related with shooting performance [30, 31]. In this line, both protocols elicited a significant increase in HR during its execution, being higher in the endurance stress protocol. This cardiovascular response could be related with the continuous impact, load and physiological demand of this type of work, a fact consequent with previous studies which compared similar exercises-based protocols [31, 32] .The HR reached during the two stress protocols is associated with a decrease in fine motor abilities and specifically in shooting, fact basic for any shoot actions independently performed by arch [33] pistol or rifle [24]. Nerveless, at the shooting moment the HR decrease below 140 bpm, HR not related with this fine motor abilities impairment. These results highlighted the importance of cardiovascular stress response control in these activities, emphasizing the importance of a good aerobic physical condition for these activities. Females presented lower isometric hand strength values at all moments evaluated. This could be explained due female phenotype, since they present lower body and muscle mass than males, lower baseline testosterone levels and lower strength in the upper body muscles [34]. Previous authors also found similar results when comparing the hand grip of active handball and judo females' athletes with healthy male soldierss, presenting males higher hand grip strength than females [35]. RPE seems to be also influenced by gender. Females presented higher RPE in the endurance and resisted physical stress protocols. These gender differences were also found in weight-bearing as treadmill [36, 37, 38], partial weight-bearing as ski machine [38], and non weight-bearing as cycle [39]. Mechanisms underlying this apparent gender difference cannot be specified, however there are several hypotheses as information processing [40] and physiological [41] differences as plausible explanations. In this line, previous authors suggested that gender differences in RPE may exist in the fact that females rate exercise as more effortful than males at absolute levels of power output [42]. Finally, a higher cardiovascular response during the protocols and while shooting at basal and endurance stress protocol was presented by females. These differences are related firstly to their smaller myocardium, beating slightly faster to make up for its size. While the average basal male heart beat is around 70–72 bpm, women beats are 78–82 bpm [43]. Secondly, the increased basal heart rate would explain the aforementioned anticipatory anxiety response, which increases the heart rate due to perceived stress and novelty of the stimuli [19]. Response that has been also evaluated in sport competition tasks [44] or in novel paratroopers before jump [45] with similar physiological response. Thirdly, the lower recovery capacity after short burst high intensity endurance activities of females [46], may explain the significantly higher shooting heart rate than males after the endurance stress protocol. BMI cutline was stablished at normo-weight (< 25 BMI) and overweight (25 BMI >). Overweighed soldiers presented greater significant values of isometric hand strength, probably explained due to the larger body mass, consequent with previous studies comparing strength of obese and non-obese soldiers of either upper [47] and lower body [48] strength. In addition, overweighed soldiers present greater marksmanship values evaluated at all moments, reinforcing the relation of hand strength and shooting marksmanships [49]. However, cardiovascular response of overweighed soldiers was significantly higher during both physical stress protocols, explained due to inferior cardiovascular performance, since for the same stimuli and intensity greater cardiovascular output is needed compared to normo-weight soldiers. Nerveless, during shooting actions their HR were similar than the normoweight group, decreasing to HR values related with no negative effect in fine motors skills. In addition, RPE was also higher in overweighed soldiers after both protocols, suggesting greater effort and exposing inferior fitness, explained due to worst physical conditioning, or the fact that being overweight is an added organic stressor [50]. In this line, previous authors correlated larger BMI with reduced cardiovascular output and lower performance, showing greater sympathetic, stress and RPE baseline values [51], supporting our present data.

Limitations of the study practical applications

The small number of soldiers is one of the main limitations of the present study, however there were no more available new infantry cadets soldiers at the moment. A second limitation was the lack of evaluation of hormones such as testosterone, alpha amylase and cortisol in order to control the hormonal stress response. These limitations were due to financial and technological lack.

Practical applications

The information of the present research could be used for specific training, allowing further individualization of the training stimulus according to gender, anthropometric and experience characteristics. In addition, soldiers, police and other security crops, as well as those sport modalities in which shooting is present, as for example biathlon, could potentially benefit from this information.

Conclusions

An endurance stress protocol produced a higher cardiovascular and perceived exertion than a resisted one, not affecting hand strength, heart rate while shooting and marksmanship. Females presented lower hand strength marksmanship and higher rated of perceived exertion and heart rate during the endurance and resisted stress protocols than males. Overweight soldiers presented higher heart rate during the stress protocols, higher hand strength and marksmanship and similar hear rate while shooting than normoweight soldiers.

Declarations

Ethical Approval and consent to participate: This investigation was performed in accordance with the Declaration of Helsinki and was approved by the University Ethic Committee and the commanding military command center.

Consent for publication: Not applicable

Availability of data and material: Not applicable

Competing interests: The authors declare that they have no competing interests in this section

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