



Caloric Expenditure and Exercise Intensity on Fighter Pilots during Combat Flight

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ABSTRACT

Rossato M, Duarte AS, Bezerra ES, Abbes PT, Silva DCS, Lima JLM, Oliveira SN, Morais MA. Caloric Expenditure and Exercise Intensity on Fighter Pilots during Combat Flight. **JEPonline** 2014; 17(2):36-43. The purpose of this study was to determine the caloric expenditure (CE) and exercise intensity (EI) on FAB F5 fighter pilots during the combat flight. There were 6 male subjects (34.8 ± 3.4 yrs; 73.3 ± 13 kg; 1.8 ± 0.1 m; 23.4 ± 2.6 kg·m⁻²). All subjects underwent a maximal progressive cycling test to exhaustion. The gas analyzer VO2000 was applied to determine VO₂ max. HR max was measured using a heart rate monitor (Polar RS400). HR was monitored during two combat flights. CE was calculated by using regression equations generated from the relationship between VO₂ and HR. EI was calculated by the percentage of HR max obtained in the tests; average values: VO₂ max (1.9 ± 0.5 L·min⁻¹); HR max (174 ± 14 beats·min⁻¹). The average CE per minute of flight and total CE were 2.9 ± 0.9 kcal and 134 ± 51.7 kcal for flight 1; and 3.1 ± 1.8 kcal and 126 ± 87 kcal for flight 2. EI remained at $56 \pm 5.5\%$ of HR max in flight 1 and $60 \pm 8\%$ of HR max in flight 2. No significant differences were found in any studied variables during flights 1 and 2. In conclusion, due to the fact that the results presented low CE and slight EI, the fatigue reported by the aviators is not the main factor for the physical wear after this type of flight.

Key Words: Calorie Expenditure, Aviation, Indirect Calorimetry

INTRODUCTION

The fighter pilot is one of the most stressful professions in the world due to the high level of responsibility and attention that an aviator must have during flight (16). Many pilots have reported fatigue at the end of the workday. Much of the fatigue results from the conditions the pilots are exposed, such as the high speed of flight, the reduced space of the cockpit, the chair immobilization by belts, tight helmets, masks that cause great discomfort on the face, diversified maneuvers, and constant alternating accelerative forces by maneuvering the aircraft. There are also concerns about the noise and vibration, the wide temperature variations, and the atmospheric radiation (12,14).

Becoming a fighter pilot is a process that involves a lot of patience and dedication, especially in dealing with the excessive workload that causes muscle aches, dizziness, headache, anxiety, increased heart rate, respiratory rate, and blood pressure (8). It is also tiring, exhausting, and often fighter pilots experience digestive disorders (8). These symptomatic organic changes may hamper the decision making of the pilots, since the capacity for concentration, attention, and memory may be compromised during combat flight.

Data provided by the Center for Research and Prevention of Aeronautical Accidents (CENIPA) indicate that between years 1989 and 1999, 36% of the aviation accidents were caused by psychophysiological changes in aviators (13). This demonstrates the need for scientific strategies to understand the physiological demands required by pilots during flight to assist the authorities in reducing the risk of accidents.

Due to the large apparatus of equipment used by pilots during flight, it becomes difficult to monitor the physiological variables (e.g., heart rate and oxygen consumption) that are commonly used in exercise physiology to identify the intensity of flight tasks (19). Without this information, it has been difficult to understand the energy demands of the pilots during flight. Fortunately, however, it is now possible to adapt a gas analyzer to the masks of pilots (18).

Many researchers (3,4,6) have used the heart rate monitoring during activities as a marker of exercise intensity and caloric expenditure, based on the fact that there is a positive relationship between heart rate (HR) and oxygen consumption (VO_2) at submaximal workloads (1). Furthermore, Spurr et al. (15) reported that there is no statistically significant difference between the energy expenditure obtained by HR and the energy expended by indirect calorimetry.

Only a few studies have investigated the work intensity of the Brazilian Air Force (FAB) fighter pilots. Palma and Paulich (12) monitored the HR of 27 FAB fighter pilots during two flights. They found that the intensity varied between 36.6% and 43.4% of HR max, and that the intensity was inversely related to aerobic condition. But, the authors did not evaluate the caloric expenditure during the performed maneuvers. Kube and colleagues (7) extended the earlier study on FAB cadets by recording their HR responses during flight. They found that the cadets HR responses were severe (58% of pilots' heart rate range, HRR) to $3.9 \text{ MET} \cdot \text{min}^{-1}$ caloric expenditure.

Thus, the purpose of this study was to evaluate the exercise intensity and caloric expenditure through regression equations of experienced FAB fighter pilots during combat maneuvers on the Amazon rainforest.

METHODS

Subjects

This study consisted of 6 male fighter pilots (34.8 ± 3.4 yrs, 73.3 ± 13 kg, 1.8 ± 0.1 m, 23.4 ± 2.6 $\text{kg}\cdot\text{m}^{-2}$; >5 yrs of experience) from the Manaus Air Force Base (BAMN). A cardiopulmonary exercise test was assigned to determine the variables related to power and aerobic capacity of the pilots. The test was performed on an ergometer bicycle (INBRAMED) at 25 W for initial load, which was increased 25 W every subsequent minute. The ergometer bicycle was chosen as the tool for the test due to the sitting position that the aviators assume during flights. The test was completed when each subject reached his maximum effort, which was defined as the pilot's inability to keep the pedaling cadence of $60 \text{ rev}\cdot\text{min}^{-1}$. The criteria used to determine the ventilatory thresholds (VT1 and VT2) were described by Wasserman and Koike (17).

During the cardiopulmonary test, maximum oxygen consumption ($\text{VO}_2 \text{ max}$) was determined by means of the Medical Graphics gas analyzer VO2000 that was calibrated according to the manufacturer's recommendations. Heart rate was monitored using a Polar HR monitor (Model RS400) in intervals of 5 sec. The HR values were recorded at the moment that preceded the increase in load.

Individual linear regression equations were generated between VO_2 ($\text{L}\cdot\text{min}^{-1}$) and HR ($\text{beats}\cdot\text{min}^{-1}$) obtained during the cardiopulmonary exercise test to, then, calculate the pilots' caloric expenditure (CE) during flights (3,5). Caloric expenditure was obtained by multiplying the number of liters of oxygen consumed during flight (obtained from the linear regression equation, Figure 1) for 5 kcal (11). The total caloric expenditure (CE/total) was divided by the flight time (in minutes) in order to calculate the caloric expenditure per minute (CE/min) for each pilot.

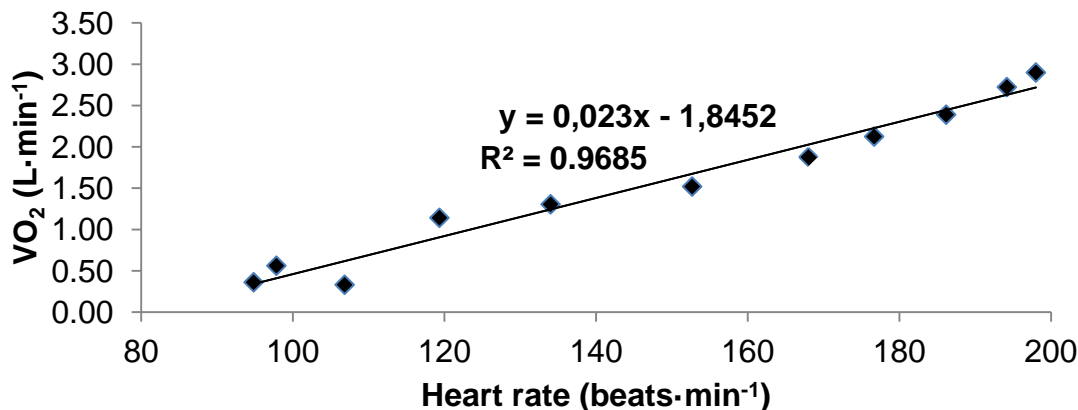


Figure 1. Regression Equation between VO_2 ($\text{L}\cdot\text{min}^{-1}$) and Heart rate ($\text{beats}\cdot\text{min}^{-1}$) with the Data Obtained during Cardiopulmonary Exercise Test in a Pilot Monitored in this Study.

The HR of each pilot was monitored during two flights. The combat flights lasted from 40 to 72 min. This type of training has the characteristics of occurring between two aircrafts (F-5 model, being a target and a hunter); both take off to a certain area of instruction, in the case of BAMN, flights are performed over the Amazon rainforest with the objective of the hunter hit the target during training (simulation).

The heart rate monitor was placed under the pilot garment. It was triggered by the pilot himself at the moment that preceded the takeoff and shut down shortly after the landing. The data obtained were transferred to specific software that calculated the average HR for each minute of flight as well as the length of flight (Figure 2).

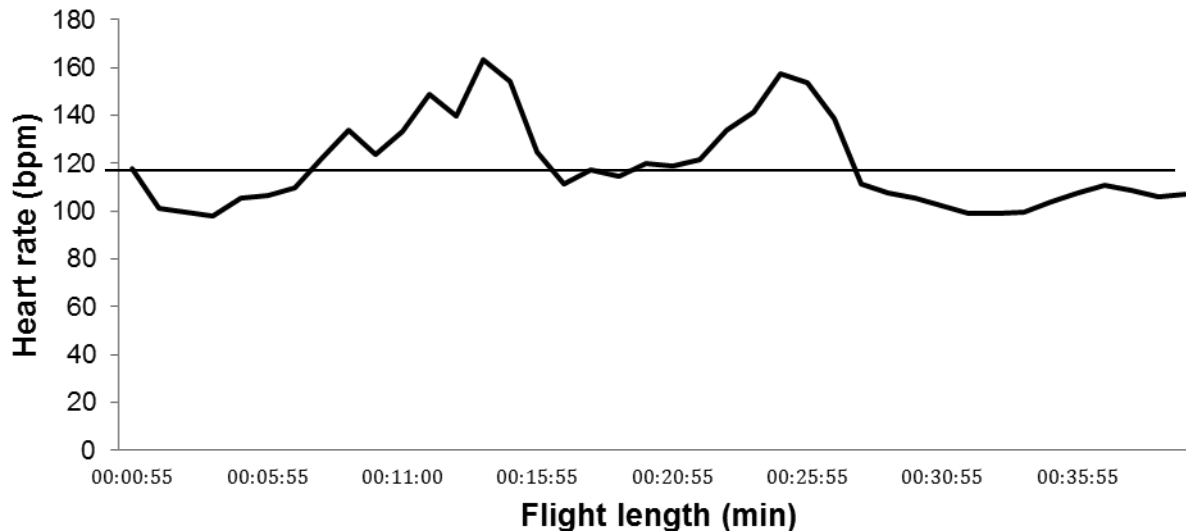


Figure 2. Heart Rate Behavior during a Flight. The Horizontal Line is the Mean Heart Rate.

The exercise intensity was calculated as a function of the mean HR during flights and HR max obtained during the cardiopulmonary exercise test. Descriptive analysis was applied (mean \pm SD) for the presentation of the results obtained in the cardiorespiratory test and also during the flights. The regression equations to determine the CE have been developed by using Microsoft Office Excel 4.0, Windows 2007 XP program. The comparison between the values of CE/min, CE/total and EI of the two flights was applied using Student's *t* test. Statistical significance was set at $P \leq 0.05$.

RESULTS

Mean values \pm SD of the physiological variables during the progressive exercise test are presented in Table 1 as the percentage of maximum heart rate (%HR max); maximum heart rate during cardiopulmonary exercise test (HR max), maximal oxygen consumption (VO_2 max), and maximum power obtained during exercise testing (P_{max}). Note that the mean HR max (174.5 ± 11.7 beats \cdot min $^{-1}$) was lower than expected for the age of the pilots, which was possibly due to the ergometer used in this study.

Table 1. The Maximum Values Obtained during the Progressive Test.

N = 6	%HR max	HR max (beats \cdot min $^{-1}$)	VO_2 max (L \cdot min $^{-1}$)	P_{max} (W)
Mean \pm SD	95 \pm 6.4	174.5 \pm 11.7	1.90 \pm 0.5	240 \pm 66

Table 2 presents the average values obtained during the progressive test for HR and power (P) at the time of ventilatory threshold 1 (VT1-HR and VT1-P, respectively) and at the ventilatory threshold 2 for HR and P (VT2-HR and VT2-P, respectively).

Table 2. Mean \pm SD for Heart Rate at Ventilatory Threshold 1 (VT1-HR), Power at Ventilatory Threshold 1 (VT1-P), Heart Rate at Ventilatory Threshold 2 (VT2-HR), and Power at Ventilatory Threshold 2 (VT2-P).

	VT1-HR (beats·min ⁻¹)	VT1-P (W)	VT2-HR (beats·min ⁻¹)	VT2-P (W)
Mean \pm SD	110 \pm 12.8	100 \pm 22.4	151.5 \pm 12.7	187.5 \pm 44.7

Regarding the variables obtained during Flight 1 and Flight 2, the mean values are shown in Table 3. No significant physiological differences were found during the two flights ($P > 0.05$).

Table 3. Mean \pm SD for Mean Heart Rate (HR mean), Maximum Heart Rate Percentage (%HR max), Flight Length (FL), Energy Expenditure per Minute (CE/min), Total Energy Expenditure (CE/total), and Metabolic Equivalent (MET) during the Two Flights.

N = 6	HR mean (beats·min ⁻¹)	%HR max	FL (min)	CE/min (kcal)	CE/total (kcal)	MET/min (mL·kg ⁻¹ ·min ⁻¹)
Flight 1	96.5 \pm 11.9	56 \pm 5.5	45 \pm 12.1	2.9 \pm 0.9	134.5 \pm 51.7	3.85 \pm 1.41
Flight 2	97 \pm 21.7	60 \pm 8.0	40 \pm 14.1	3.1 \pm 1.8	126 \pm 87.2	4.02 \pm 2.39

DISCUSSION

This study found that the Brazilian Air Force (FAB) fighter pilots' average VO_2 max value was 1.90 ± 0.5 L·min⁻¹. This value may have been affected by the ergometer used, since it presents lower involved muscle mass than when tested on a treadmill. This occurred because an attempt was made to approximate the characteristics of the labor activity of the pilots. Hence, the cycle ergometer was used rather than the treadmill to monitor aerobic power (VO_2 max) in the seated position. Also, it is possible that this decision may have influenced the assessment of the related variables to aerobic capacity (VT1 and VT2).

McArdle et al. (11) assert that, when aerobic power is evaluated on a cycle ergometer, it tends to be lower when compared to the aerobic power response on a treadmill. The difference is assumed to be due to the use of less muscle mass and, therefore, a lower energy demand. It is likely that the less muscle mass required of the lower extremity vs. using the arms and legs during running may explain the low VO_2 max of 1.90 ± 0.5 L·min⁻¹. According to ACSM (2), the pilots' values are classified as weak conditioning. Moreover, it should be noted that the pilots' HR max percentages were well below their predicted ($95 \pm 6.4\%$).

As to the pilots' HR responses during the flights, no significant differences were observed. Lucía et al. (10) assert that the intensities below VT1 are considered low, intensities between VT1 and VT2 are considered moderate, and above VT2 are considered intense. The mean HR data observed for flight 1 (96.5 ± 11.9 beats·min⁻¹) and for flight 2 (97 ± 21.7 beats·min⁻¹) were both below the average HR corresponding to VT1 (110 ± 12.8 beats·min⁻¹). This indicates that the mean intensities of both flights are considered low. This condition is also evidenced by the percentage of maximum HR obtained during the cardiopulmonary exercise test (%HR max) while flight 1 was 56% and flight 2 was 60%. According to ACSM (2), intensities between 50 and 63% of HR max and metabolic equivalent from 2.4 to 4.5 METs for people with VO₂ max similar to those observed in the pilots VO₂ max are considered slight.

The variables observed above demonstrate that flights have similar characteristics of intensity. The length of flight oscillated from 40 to 70 min. However, the mean for the first flight was 45 ± 12.1 min and 40 ± 14.1 min for the second flight. Both the values of CE/min and the CE/total did not differ significantly between flight 1 and flight 2. The CE/total was higher in flight 1 (134.5 ± 51.7 kcal) due to the longer flight time in comparison to flight 2.

One of the few studies that assessed intensity and caloric expenditure in aviators was carried out by Kube (7). The research by Kube (7) investigated 10 cadets of the 4th-yr from the Aviators Training Centre (CFOAV) of the Air Force Academy (AFA) in different tasks, including instructional activities directly related to flight (pre-flight, flight, and post-flight). The results related to the percentage of heart rate reserve (HRR%) showed that the activity of the flight was considered severe (58%); pre-flight (29%) and post-flight (24%). These responses were considered moderate activities. The highest effort intensity during flight activities found in the study by Kube (7) was due possibly to the fact that the pilots were under training, which would generate a greater stress to the cardiovascular system (via the adrenergic system and respective responses). It is important to highlight that Loures et al. (9) showed that caloric expenditure was 3.9 MET·min⁻¹ during flight activities, which is very close to those shown in the present study: 4.02 ± 2.39 MET·min⁻¹ (flight 1) and 3.85 ± 1.41 MET·min⁻¹ (flight 2).

CONCLUSION

This study concludes that the effort intensity of the fighter pilots during combat flights over the Amazon is considered low, requiring very low calorie consumption. Thus, the fatigue reported by the aviators is not the main factor for the physical wear after this type of flight.

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