# 73 - DETERMINATION OF TIME UNTIL EXHAUSTION IN THE CRITICAL FORCE INTENTENSITY

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**Introduction**

In cycle ergometer exercise, the relationship between power and time to exhaustion (TTE) is described by a hyperbolic model (Moritani et al 1981). This term was originally proposed for use with synergistic muscle groups and has been adapted to total body work in sporting activities such as cycling (Jenkins, 1992). This model is the basis of the critical power concept (Hill 1993). With regard to total body work in swimming and running, critical velocity (Vcrit) is defined as the speed which can theoretically be maintained indefinitely without exhaustion (Wakayoshi, 1992). In isometric strength, to generate a force-duration (F-D) graph, a volunteer is asked to maintain different isometric force levels (e.g. using biceps muscle with elbow at 90°) for as long as possible on separate occasions. The curve shows a horizontal asymptote at about 15% of maximal voluntary contraction. This asymptote represents critical force (CF). Theoretically, forces below this value can be held indefinitely. Of course there will be unique mechanical and physiological limitations at either extreme of the F-D relation. Above CF, there is a limit to how long force can be maintained. However, for resisted exercises (dynamic force), yet there are no research determining time until for exhaustion in the intensity of the dynamic critical force.

Lactate threshold (LT) is defined as the submaximal exercise intensity that invokes a sudden and sustained increase in blood lactate concentration (Kumagai, 1982). Increased lactic acid production results from the onset of anaerobic glycolysis to supplement aerobic energy production at an individual specific exercise intensity. The associated increase in H+ with increasing lactic acid results in metabolic acidosis, a primary vehicle of fatigue. The underlying mechanics of LT clearly indicate that at exercise intensities up to the LT, where minimal energy is supplied by anaerobic glycolysis, exercise could be maintained for a prolonged period of time without fatigue.

During the accomplishment of resisted dynamic contractions, the energy can be supplied by aerobic mechanisms, since the solicitation keeps below 30% of the maximum force (1RM) (VILLIGER et al.1995). Thus, it was certain for DE AGOSTINI & BALDISSERA (2000), which lactato threshold it situates in 30% of the 1RM, intensity this enough to cause occlusion of the capillary by the elevated inter-muscular pressure (PETROFSKY,1984). This hipóxia caused muscular accelerates for glicólise causing in the initiate of lactate accumulation (WASSERMAN et Al. 1986).

In cycling, running and swimming, several researches demonstrated that the intensity of the speed and/or of the critical power is supplies lactate threshold, indicating how the same will not be able to be kept for a long time. Martin and Whyte (2000), determined in triathletes of elite, that critical velocity was greater than the velocity of lactate threshold in swimming.

Although the aims of the investigation were not to validate Vcrit from a theoretical perspective, the findings of the study of Martin and Whyte (2000) have resulted in the need to question the physiological meaning of critical velocity from the current definition.

Based in these data, the purpose of this study is to determine the critical force intensity and the number of repetitions made until the exhaustion of it.

**Methods - Subjects**

Twelve male physical education students participated in this study. All subjects were volunteers and gave their written consent to participate in these experiments. Their mean± standar desviations (SD) for age, mass and height were 22,21 ± 2,48 years; 78,58±8,78 kg and 1,83±0,076cm, respectively.

**Experimental protocol**

All subjects performed.four tests until exhaustion at the same time of the day to minimese the effects of diurnal biological variation, separed by at least 48 h, but all were completed within 4 weeks. For each test, subjects were verbally encouraged to continue for as long as possible. The subjects were considered as exhausted when they could not mantain the required speed associated with visible exhaustion.. Before the tests the subjects ere familiarised with the exercise procedure and with the analyses. The subjects were required to rest the day before the test and to have their last meal 2 hours before the test. These 4 tests were preced by a standardised warm up wich consisted of 3 minutes of ergometer cycle. The test began imediatly after this warm up.All test were performed in a leg press machine where the individual must do the complete extention of knee and it was limited to 90º when it comes back. The first test was 80% of 1RM(RM, this was known from previous experience in the laboratory), the second one was 50% of 1RM, the third test was 20% of RM and the last one was the critical force. The subject might do the test until they couldn´t mantain it anymore. Heart rate(fc) was determined by Polar 810 i.

**Determination of critical force**

The critical force was determine by the exponencial equation beteween maximal load intensity and reverse time until a exhaustion in the three pre-determineted intensities.

**Determination of lactate threshold:**

Capillary blood samples were taken in rest and five minutes after the accomplishment of each test. The fingertip was cleaned with an alcohol swab,dried and then punctured with an manual lancet before 50 µl of blood was collected into a capillary tube. Blood samples were analysed for [la] in duplicate using an automated analyser (YSI 1500 Sport, Yellow Springs).

**Determination of Statics:**

Descriptive statistical results were expressed in terms of sample average and standar deviation(SD). Test t Student was used for independent samples. In all cases, the significance level was $p<0,05$.

**Results**

The description of volunteers to variables; corporal mass, height and age, is represented in the below. The values are express for average and standard desviation. Table 1: Volunteers descriptions

| Variables | Resultados |
|---|---|
| Age(years) | 22,21 ± 2,48 |
| Height(m) | 1,83 ± 0,07 |
| Corporal mass (kg) | 78,58 ± 8,78 |

The table 2 ilustrates the number of repetitions made until exhaustion in each one of four intensities tested. The values are express for average and standard desviation.

Table 2: Maximal repetitions for each exercise intensity

| Variables | 80% 1RM | 50% 1RM | 20% 1RM | 18,11% 1RM |
|---|---|---|---|---|
| RM | 14,78 | 39,44 | 206,11 | 406,27 |
| DP | 5,78 | 11,63 | 136,63 | 339,51 |

Like ilustred in the last table, the maximum number of repetitions until exhaustation were 14,78 5,78 to 80% 1RM; 39,44 11,63 to 50% 1RM; 206,11 136,63 to 20% 1RM and 406,27 339,51 to 18,11% 1RM. The last one is the critical force instensity.

The table 3 ilustrates the lactate concentration pré and five minutes after the accomplishment of the maximum repetitions for each one of the four intensities tested.The values are express for average and standard desviation.

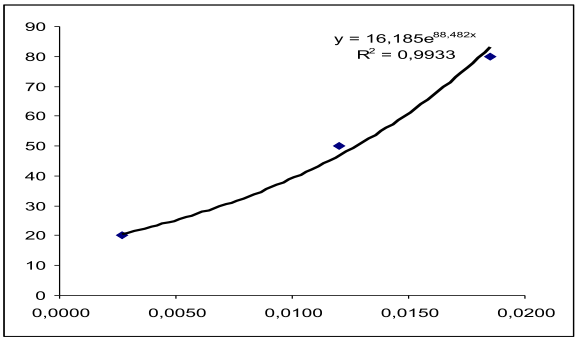
Table 3: Lactatemia Values

| Variables | 80% 1RM | 50% 1RM | 20% 1RM | 18,11% 1RM |
|---|---|---|---|---|
| [Lactate | 7,48 | 9,03 | 6,22 | 2,65 |
| SD | 2,78 | 2,59 | 2,92 | 1,24 |

Like ilustrated in the table 3, the lactemia values were 7,48 2,78; 9,03 2,59; 6,22 2,92 e 2,65 1,24 respectively 80, 50, 20 e 18,11% (critical force) 1RM.

The graph below demonstrates the critical force for a volunteer. The value of Y represents the interseption point beteween the intensity of the maximum force and the inverse of the time, which theoreticallly could be kept indefinitely without exhaustion.

Axle Y represents the intensity percentual of the maximum force, axle X represents the inverse of time for each one of the 3 intensities tested until the exhaustion.




**Discussion**

The purpose of this study was to determine the number of repetiton made until exhaustion in the critical power intensity and, the concentration of lactate relate to each load intensity. Like demonstrated in the results, there is a reverse relacion betewen intensity of exercise and maximal number of repetiton, indicating that fadige is acelerated when the load is increasing. However, when the lactate concentration is analyse to each percentual of maximal load, the values of lactate concentration to 50% 1RM were significantly better than the 80 and 20% of maximal force. Even if fadige causes don´t be the purpose of this study, we know that various factors can decide the appear of fadige during the exercise, like a acidosis. The decrease of creatine phosfato stores(CP) and accumulate of inorganic phosfato(Pi) appears like a main causes of acidosis during the heigh intensity excersises . In intenstity under the thersold lactate, factors like hypertermic, dehidratation, decrease of glycogenic stores and decrease of excitability of central nervous system decide a interrupcion of excercise above the exhaustion.

Studies of DE AGOSTINI E BALDISSERA (2000), determined the existence of lactate thersold in load next 30% 1RM, the intensities of 80 and 50% 1RM were supra thersold,it means big possibility of acid fatigue(7,48 e 9,03 mM of lactate concentracion, respectively. Lactate concentracion in 50% 1RM is bigger than 80% 1RM because the longer time of glicolitic utilization. The degratation of CP in this intensity is smaller for each repetion. Westerblad et al. (2002), the speed up rhythm of CP use, increases the concentration of Pi, which speeds up the fatigue for inhibiting diverse places of the contráctil process.

The lactatemia values (6,22 mM) 20% of the 1RM had been considered raised, since the intensity is placed below of the lactate threshold in resisted exercise. However the acidosis is not necessarily the agent causing of fadique in this intensity, because in resisted contractions, more intense (60 70% 1RM) until the exhaustion, the values of lactate had placed around 9 the 12 mM (OF AGOSTINI and BALDISSERA, 2000).

According to HOLLMANN & HETTINGER (1989), the resisted performance in sub- thresholds intensities depends to delivery intracellular oxygen, the capacity of mitocondrial metabolism and the nutrients storaged in the glycogen form, as well as, the quality of the metabolic processes. Any one of these factors can have influenced the appearance of fatigue.

Another purpose of this study was to determine the critical force intensity and the number of repetitions made until the exhaustion of it. This value was 18,11% 1RM, with the number of repetitions 406,27±339,51. It is significantly bigger than 80 and 50% 1RM intensities. Differently of critical power and critical velocity, which had been supply lactate threshold (Martin and Whyte 2000), the critical force were placed bellow the lactate threshold , indicating that theoreticallly it could be kept indefinitely for a long time. However, the critical force express a mathematical equation and not a physiological phenomenon. That is why, factors related with exhaustion in intensities sub thresholds, also could be possible involved in the fatigue cause in the intensity of it.

**Conclusion:**

Through these results we can conclude that the critical force value is smaller than lactate threshold intensity in resistence exercise, promoting raised number of repetiton until exhaustion. However for being a physiological phenomenon and not mathematician, the fatigue still is evident.

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**Key words**: Critica force, Lactate threshold and exhaustion time.

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**DETERMINATION OF TIME UNTIL EXHAUSTION IN THE CRITI FORCE INTENTENSITY**

Introduction: The critical power and velocity are basic concepts to study fadigue and exhaustion in not resisted dynamic exercises. However there isn´ t so much knowledge about the behavior of the exercise in the critical force intensity. Objective: The aim fo this study was to determine the critical force intensity and the number of repetitions made until the exhaustion of it. Method: Twelve masculine volunteers with average age of 22,21 ± 2,48;and 78,58±8,78 weight.They did four tests until voluntary exhaustion on leg press 45º machine. The three first tests had been done variedly beteween 80, 50 and 20% 1RM intensities, and had been used to determinate the critical force by exponential equation. After determination of corresponding critical force intensity, the voluntaries did a last test until exhaustion. Blood Samples (25ul) had been collected in rest and five minutes after the accomplishment of each test, for lactatemia determination. Results: The values of the maximum number of repetitions for each maximum load intensity were 14,78 ±5,78 for 80% 1RM; 39,44 ±11,63 for 50% and 206,11 ±136,63 for 20% 1RM. The number of maximal repetitions done in the critical force intensity were 406,27±339,51. The values of lactatemia were 7,48±2,78; 9,03± 2,59; 6,22 ± 2,92 and 2,65 ± 1,24 respectively for 80, 50, 20 and 18.11% (critical force) 1RM. Conclusion: Through these results we can conclude that the critical force value is smaller than lactate threshold intensity in resistence exercise, promoting raised number of repetiton until exhaustion. However for being a physiological phenomenon and not mathematician, the fatigue still is evident.
**Key words**: Critical force, Lactate threshold and exhaustion time.

**DÉTERMINATION DU TEMPS JUSQU'À L'EXHAUSTION DANS L'INTENSITÉ DE LA FORCE CRITIQUE**

Introduction: La puissance et la vitesse critique sont des concepts fondamentaux pour l'étude de la fatigue et de l'exhaustion dans des exercices dynamiques non résistés. Néanmoins peu si sait sur le comportement de l'exercice dans l'intensité de la force critique. Objectif: L'objectif de ce travail a été déterminer l'intensité de la force critique et le nombre de répétitions réalisées jusqu'à l'exhaustion dans l'intensité de la même. Méthode: Douze volontaires du type masculin avec âge moyen de 22,21 ± 2,48 et poids 78,58±8,78 ont réalisé quatre essais jusqu'à l'exhaustion volontaire à l'exercice “Leg Press 45”. Les trois premiers essais ont été réalisés aléatoirement dans les intensités de 80,50 et 20% de la 1RM, et ont été utilisés pour détermination de la force critique, au moyen d'équation exponentielle. Après détermination de l'intensité correspondante à la force critique, une chambre a expérimenté jusqu'à l'exhaustion a été réalisée. Des échantillons de sang (25ul) ont été rassemblés dans repos et cinq minutes après la réalisation de chaque essai, pour détermination de la lactatemie. Résultats: Les valeurs du nombre maximum de répétitions pour chaque intensité de charge maxime ont été de 14,78 ±5,78 pour 80% de la 1RM ; 39.44 ±11.63 pour 50% et 206.11 ±136.63 pour 20% de la 1RM. Le nombre de répétitions maximes réalisées dans l'intensité de la force critique a été 406,27±339,51. les valeurs de la lactatemia ont déjà été de 7.48 ±2.78 ; 9.03 ±2.59 ; 6.22 ±2.92 et 2.65 ±1.24 respectivement pour 80.,50.,20 et 18,11% (force critique) de la 1RM. Conclusion: Par moyen de ces résultats nous pouvons conclure que la valeur de la force critique est mineur que l'intensité du seuil de lactate dans exercice résisté, promouvant élevé nombre de répétitions jusqu'à l'exhaustion. Néanmoins d'être un phénomène physiologique et non mathématique, la fatigue encore est évidente.
Mót-clés: temps jusqu'à l'exhaustion , force critique, la lactatemie

**DETERMINACIÓN DEL TIEMPO HASTA LA EXAUSTION EN LA INTENSIDAD DE LA FUERZA CRITICA**

La potencia y la velocidad criticason conceptos fundamentales para el estudio de la fatiga e exaustión en ejercicios dinámicos no resistidos.Entretanto poco se puede saber sobre el comportamento del ejercicio en la intensidad de la fuerza critica. Objetivo: El objetivo deste trabajo fue determinar la intensidad de la fuerza critica y el número de repeticiones realizadas hasta la exaustión en la intensidad de la misma. Métodos: Doce voluntarios del gênero masculino con edad média de xx( yy y peso yy ( xx hicieron cuatro testes hasta laexaustión voluntaria en el ejercicio Leg Press 45. Los tres primeros testes fueron realizados aleatoriamente en las intensidades de 80, 50 y 20% de 1RM, y fueron utilizadas para determinación de la fuerza crítica, por medio de ecuación exponencial. Após determinación de la intensidad correspondiente a la fuerza crítica, uno cuarto teste hasta la exaustión fue realizado. Amostras de sangre (25ul) fuerón colectadas en repouso y cinco minutos después de la realización de cada teste, para determinación de la lactemía. Resultados: Los valores del número máximo de repeticiones para cada intensidad de carga máxima fueron de 14,78 ( 5,78 para 80% de 1RM; 39,44 ( 11,63 para 50% y 206,11 (136,63 para 20% da 1RM. El número de repeticiones máximas hechas en la intensidad de la fuerza crítica fue de xx (yy. Mientras, los valores de la lactatemía fueron de 7,48 ( 2,78; 9,03 ( 2,59; 6,22 ( 2,92 e 2,65 (1,24 respectivamente para 80, 50, 20 y 18,11% (fuerza crítica) de 1RM. Conclusión: Por el medio destes resultados se puede concluir que el valor de la fuerza crítica es menor que la intensidad del liminar de lactato en ejercicio resistido, promoviendo elevado número de repeticiones hasta la exaustión. Entretanto por ser un fenómeno fisiológico y no matemático, la fatiga todavía es evidente. Palabras llaves: Fuerza critica, limiar de lactato e tiempo hasta la exaustion

**DETERMINAÇÃO DO TEMPO ATÉ A EXAUSTÃO NA INTENSIDADE DA FORÇA CRÍTICA**

Introdução: A potência e a velocidade crítica são conceitos fundamentais para o estudo da fadiga e exaustão em exercícios dinâmicos não resistidos. Entretanto pouco se sabe sobre o comportamento do exercício na intensidade da força crítica. Objetivo: O objetivo deste trabalho foi determinar a intensidade da força crítica e o número de repetições realizadas até a exaustão na intensidade da mesma. Método: Doze voluntários do gênero masculino com idade média de 22,21 ± 2,48 e peso 78,58±8,78 realizaram quatro testes até a exaustão voluntária no exercício Leg Press 45º. Os três primeiros testes foram realizados aleatoriamente nas intensidades de 80, 50 e 20% da 1RM, e foram utilizadas para determinação da força crítica, por meio de equação exponencial. Após determinação da intensidade correspondente à força crítica, um quarto teste até a exaustão foi realizado. Amostras de sangue (25ul) foram coletadas em repouso e cinco minutos após a realização de cada teste, para determinação da lactatemia. Resultados: Os valores do número máximo de repetições para cada intensidade de carga máxima foram de 14,78 ± 5,78 para 80% da 1RM; 39,44 ± 11,63 para 50% e 206,11 ±136,63 para 20% da 1RM. O número de repetições máximas realizadas na intensidade da força crítica foi de 406,27±339,51. Já os valores da lactatemia foram de 7,48±2,78; 9,03±2,59; 6,22±2,92 e 2,65 ±1,24 respectivamente para 80, 50, 20 e 18,11% (força crítica) da 1RM. Conclusão: Por meio destes resultados podemos concluir que o valor da força crítica é menor que a intensidade do limiar de lactato em exercício resistido, promovendo elevado número de repetições até a exaustão. Entretanto por ser um fenômeno fisiológico e não matemático, a fadiga ainda é evidente.Palavra chave: força critica, limiar de lactato e tempo até exaustão.